Process Integration
Concepts, Tools and Strategy for the Future

Petar Sabev Varbanov

Centre for Process Integration and Intensification – CPI^2
Research Institute of Chemical and Process Engineering
Faculty of Information Technology

University of Pannonia, Veszprém, Hungary

TÁMOP-4.1.1.C-12/1/KONV-2012-0017

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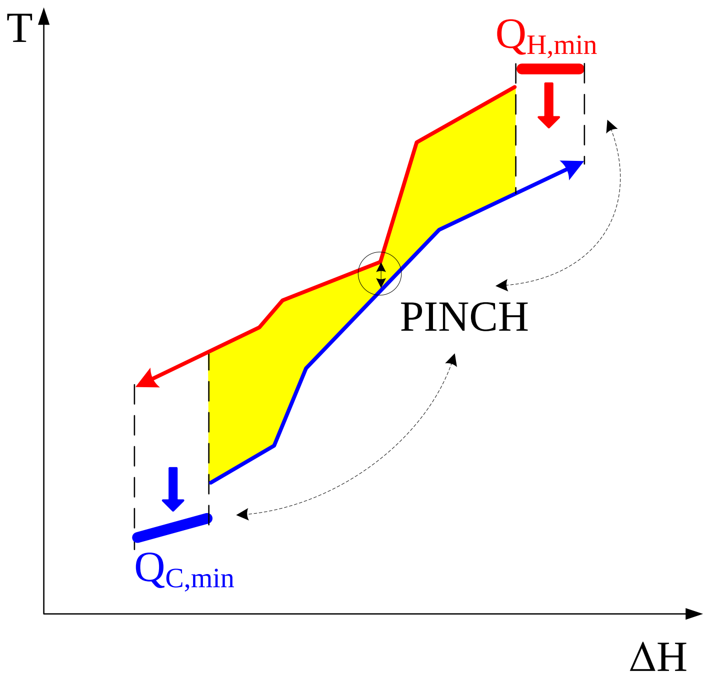
The project is supported by the European Union and co-financed by the European Social Fund.

Outline

- The University
- Introduction
- Sustainability: the starting point
- Process Integration
- Challenges to consider
- Summary / Suggestions
- Conclusions



Location

NEW SZÉCHENYI PLAN

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University of Pannonia

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Faculty of Information Technology

- Training and research in Information Technology, Nanotechnology and Electrical Engineering
- Close cooperation with the industry in R & D
- **Research Institute of Chemical and Process Engineering**

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NEW SZÉCHENYI PLAN

A Key Opportunity

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Project Period: **15 April 2013 – 14 April 2015**

Total funding granted by the European Union and the Hungarian Government:

1.288.968.656 HUF

<u>**Main beneficiary name, address:**</u>

University of Pannonia

H-8200 Veszprém, Egyetem street 10

"Green Energy" – Cooperation of the higher education sector for the development of green economy in the area of energetics

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Green Energy Project:

Innovative cooperation - *cooperative* innovation

EU funded multiplayer organizational development project
for establishing the Green Energy Center in Hungary

Zoltán Butsi

director of Project Directorate of the University,
professional leader of the Green Energy project

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1. Cooperation at Stakeholders' Level

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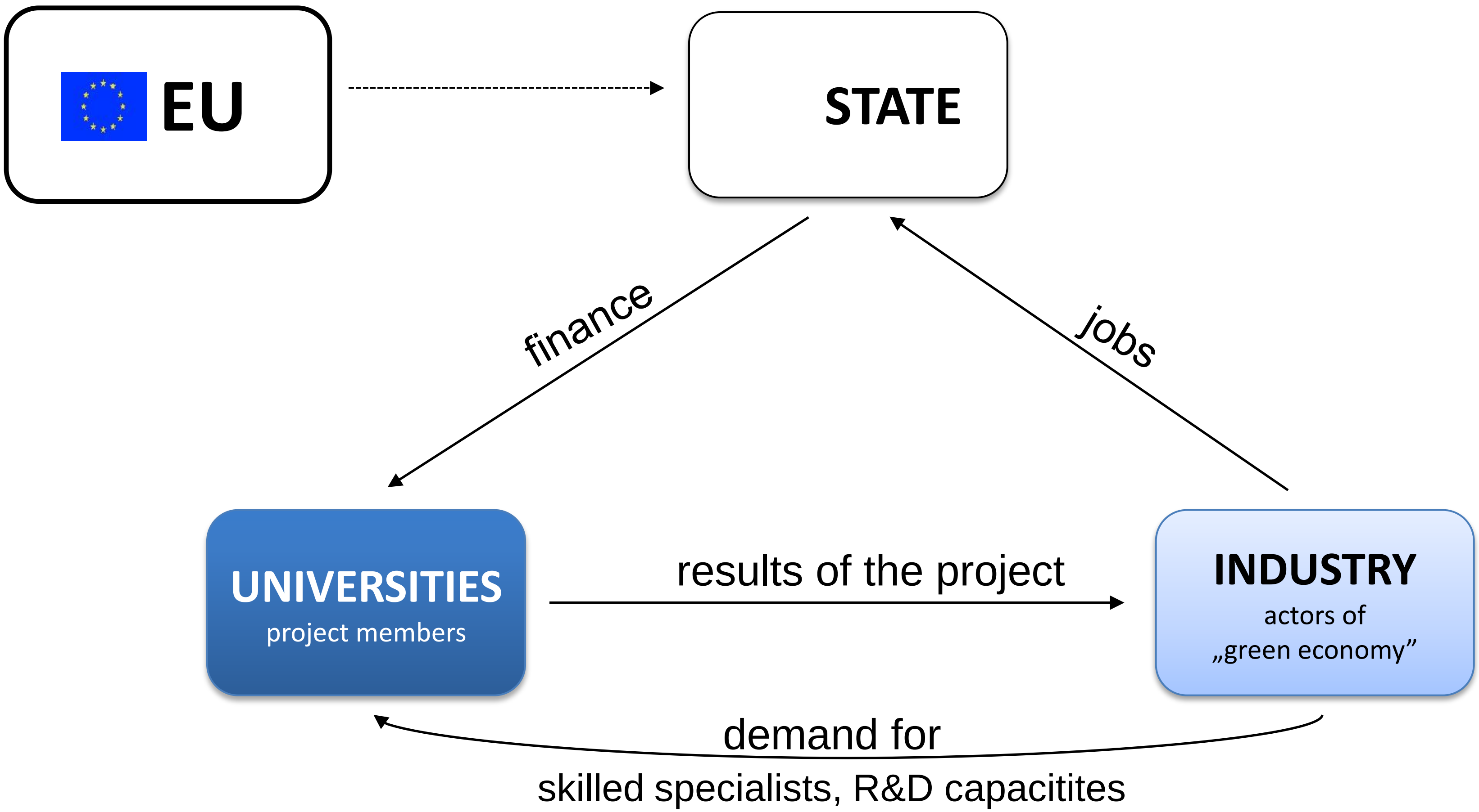

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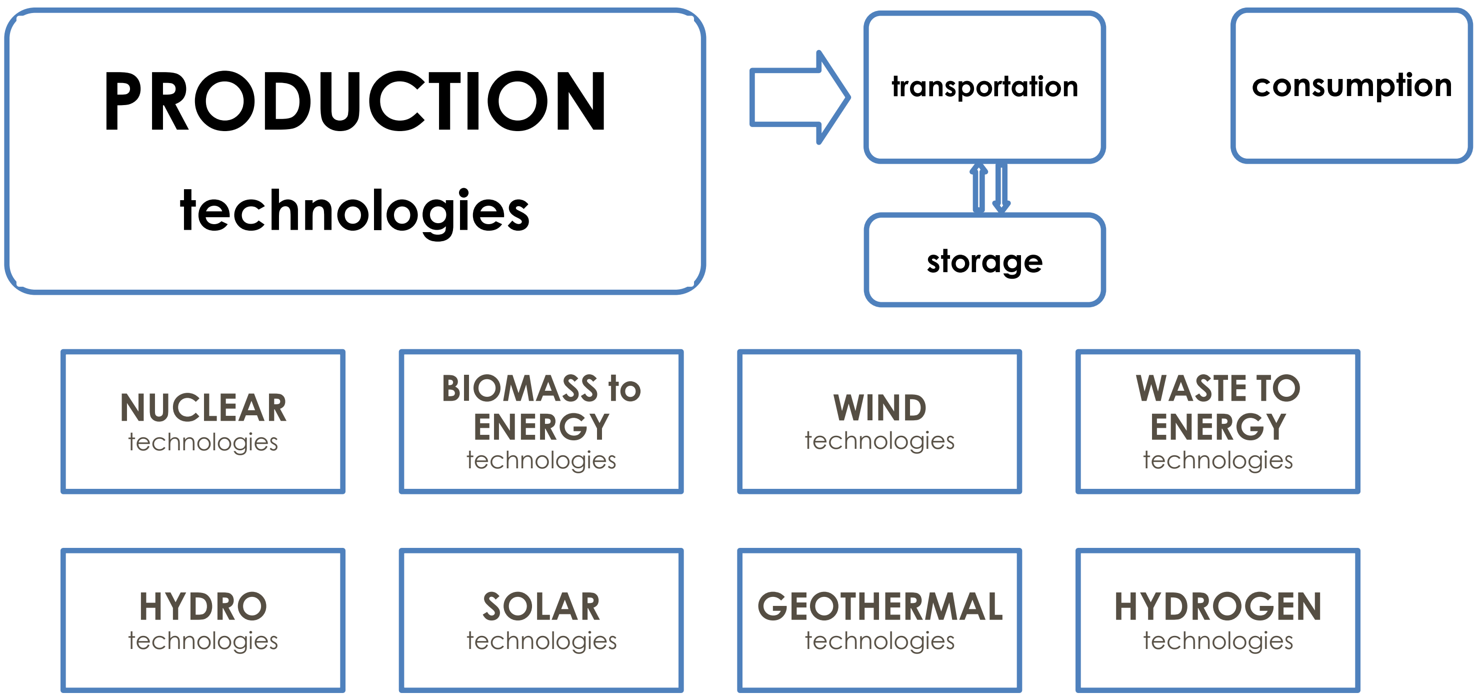
2. Cooperation in professional level

Pursuing **optimization** instead of ”race” between the energy sources:



The principle of the project – OUR JOB is:NOT to replace traditional energy sources with renewables by any means,

- BUT to develop scientific **methods**, **experts** and **services** for achieving the **optimized energy-mix** based on the locally available sources

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3. Cooperation in consortium level

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Consortium members :

- University of Pannonia (Leader), Veszprém [NUCLEAR, WASTE, HYDROGEN, GEOTHERMAL]
- Széchenyi István University, Győr [WIND]
- University of Kaposvár, Budapest [BIOMASS]
- Edutus Nonprofit Ltd., Tatabánya [SOLAR]
- International Lean Sigma Alliance, Budapest [INDUSTRIAL BACKGROUND]

(share of task and responsibilities)

Project period: 15 April, 2013 – 14 April, 2015

Financing:

The project is financed by the EU/Hungarian Social Renewal Operational Program, which support the cooperation in the higher education sector for the development of green economy in the area of energetics.

Total funding granted by the European Union with the Hungarian Government: **1.288.968.656** HUF (5,85 million $)

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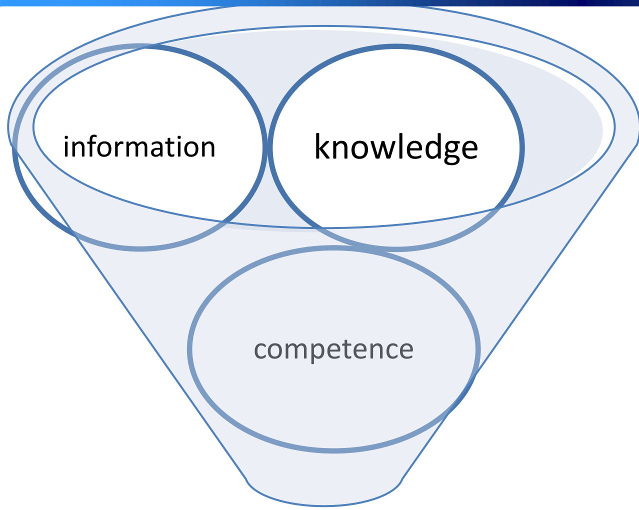
4. Cooperation in organizational level



Industry, Society, Users

III. Institutional Services

- Start/continue innovation projects in collaboration with industry
- Create public service portfolio (career services)

II. Education

- Synchronization of the labour-market needs and the professional output of the higher education
- Enhance the willing of study in Hungary as well as broaden and strenghten the international academical relations, cooperations.
- Involvement of industrial partners in training
- Digital content (curriculum) development

I. Knowledge cluster (R&D)

- Creating an international professional network
- Creating a knowledge cluster
- Mapping intellectual potential, R & D assets (To create the research coordination in
- favor of the better utilization of research capacities)
- Comprehensive studies to assist decision-making

SZÉCHENYI PLAN

How to deal with a complicated problem?

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George Pólya - Pólya György

13 December 1887 – 7 September 1985

He was one of the giants of classical analysis in the 20th century, and the influence of his work can be seen far beyond analysis, into number theory, geometry, probability and combinatorics

G. Pólya, How To Solve It: A new aspect of mathematical method, Princeton University, 1945
G. Polya, How to Solve It, 2nd ed., Princeton University Press, 1957
<www-history.mcs.st-andrews.ac.uk/Mathematicians/Polya.htm>

<www.britannica.com/EBchecked/topic/468249/George-Polya>

Pólya's Four Principles

1. Understand the problem
2. Devise a plan
3. Carry out the plan
4. Review/Extend

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Sustainability
Ideas and Concepts

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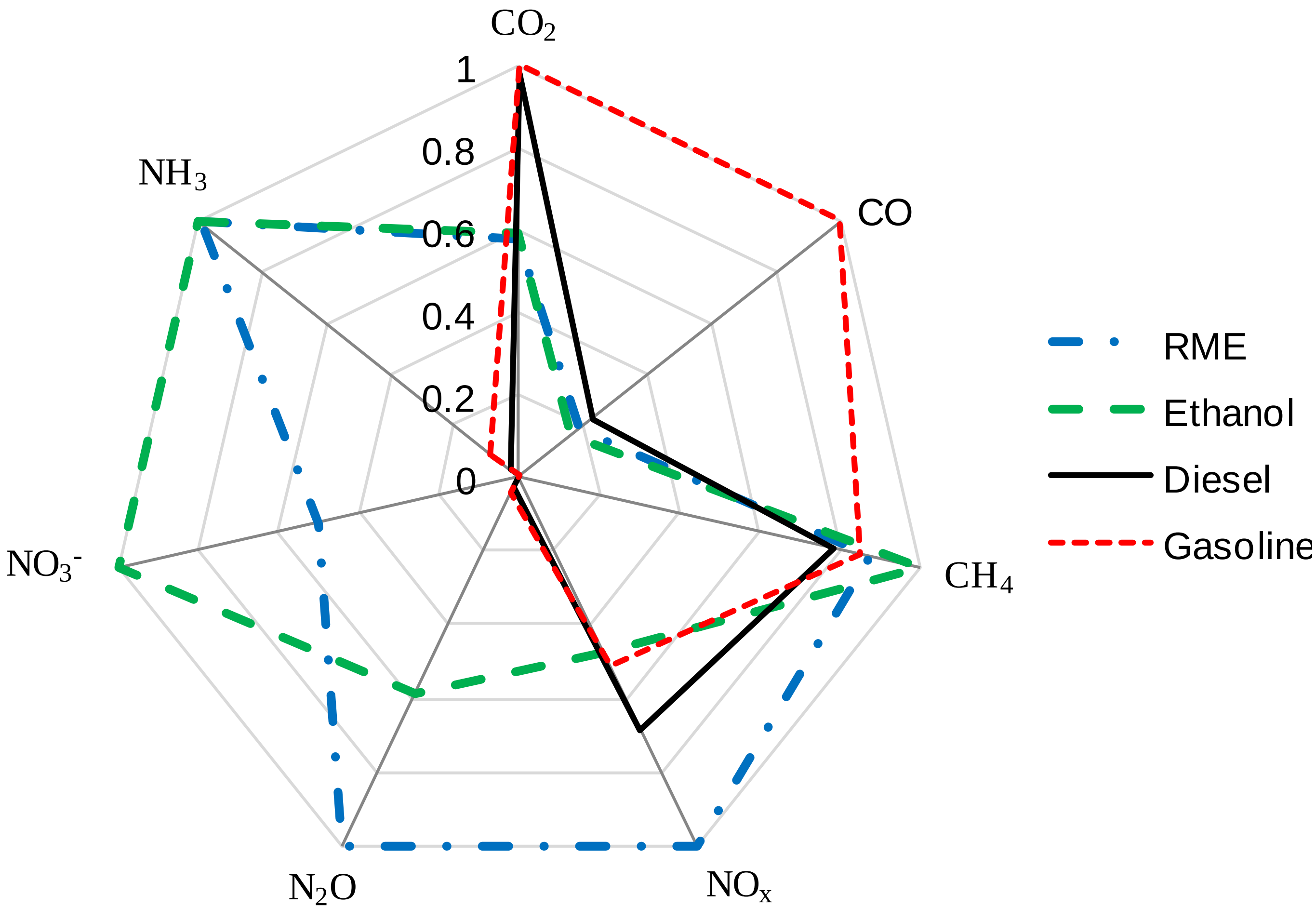
Indicators of environmental impact dealing with the potential effects and impacts on humans, environmental health and resources come from the LCI

Saur K., 1997, Life Cycle Impact Assessment, The International Journal of LCA, 2, 66-70

Impact potentials:

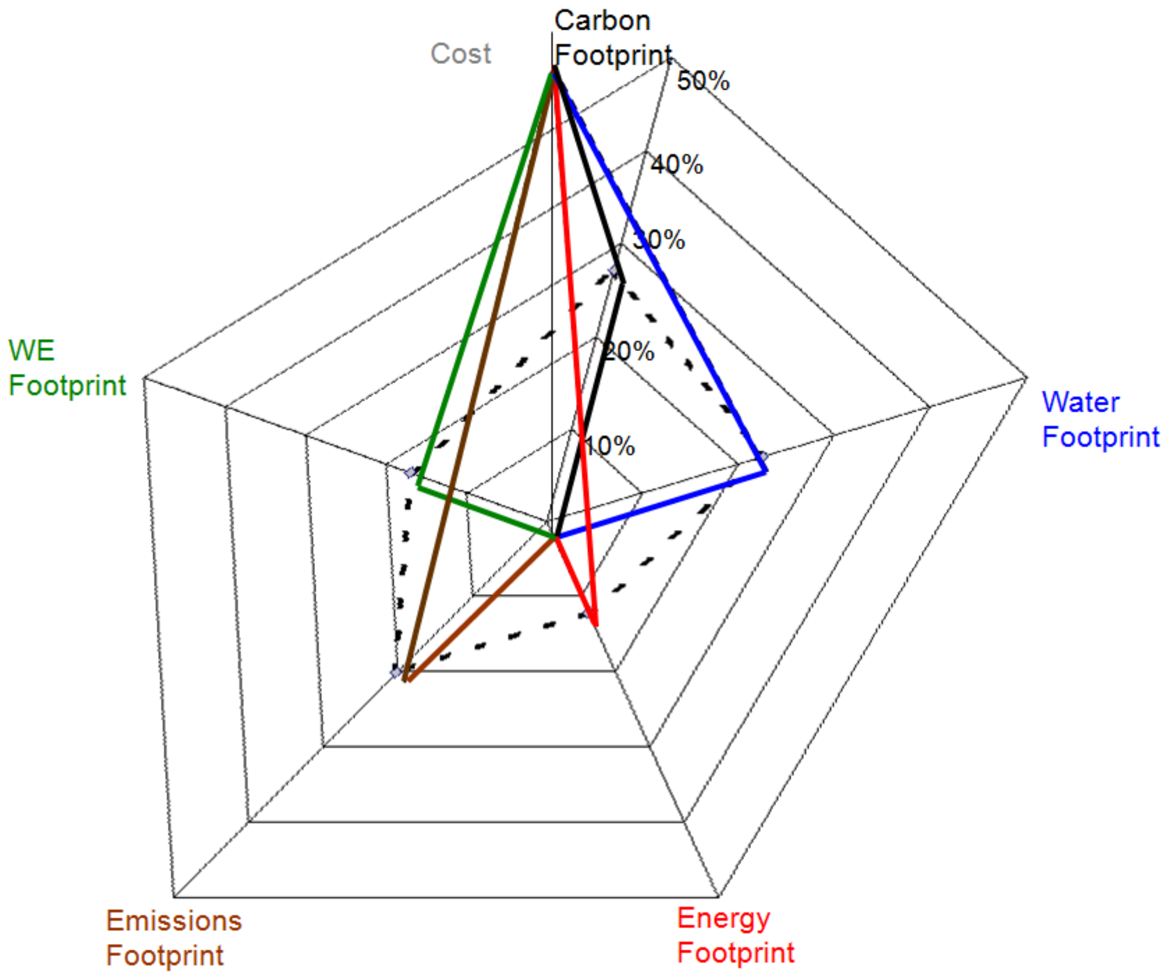
- Global warming potential
- Acidification potential
- Eutrophication potential
- Human toxicity potential
- Ozone depleting potential etc.

Consider All Relevant Indicators



Čuček, L., Klemeš, J., Kravanja, Z. (2012). Carbon and nitrogen trade-offs in biomass energy production. Clean Technologies and Environmental Policy, 14, 389-397.

Another Representation



De Benedetto L., Klemeš J., 2009. The Environmental Performance Strategy Map: an integrated LCA approach to support the strategic decision-making process. Journal of Cleaner Production, 14, 900-906.

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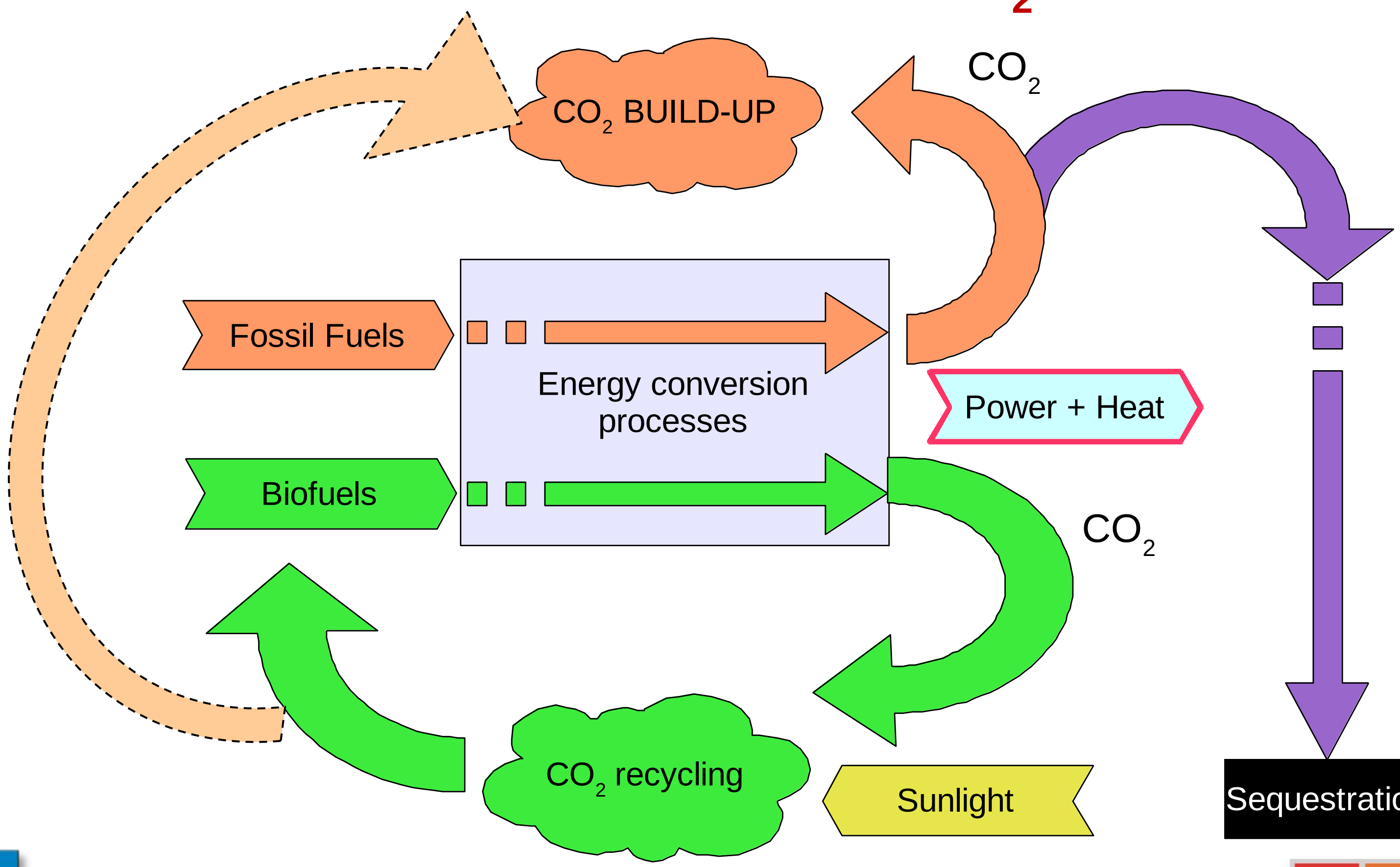
Reduce resource consumption preserving quality of life?

CO_2 / Carbon Paths



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- Describes a problem as a set of equations
- An objective function

Minimize (or maximize) $F(\mathbf{x}, \mathbf{y})$	Objective function, performance criterion
where $\mathbf{x} \in \mathbf{R}^n$ (continuous variables)	Continuous domain
$\mathbf{y} \in \mathbf{Z}^n$ (integer variables)	Discrete domain
subject to $h(\mathbf{x}, \mathbf{y}) = 0$	Equality constraints
$g(\mathbf{x}, \mathbf{y}) \leq 0$	Inequality constraints

Powerful Tool

- There are a number of environments for developing and solving mathematical models: GAMS, LINDO, IBM-ILOG Studio, etc.
- A variety of solvers for solving successfully LP, NLP, MILP, MINLP problems
- Solution times are constantly being reduced as a result of novel algorithms as well as hardware development

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Process Integration: Iintroduction

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What is Process (Heat) Integration?

- A family of methodologies for combining several processes to reduce consumption of resources or harmful emissions to the environment
- It started as mainly heat integration stimulated by the energy crisis in the 1970's

- Definition of Process Integration by IEA:
  - Systematic and General Methods for Designing Integrated Production Systems ranging from Individual Processes to Total Sites, with special emphasis on the Efficient Use of Energy and reducing Environmental Effects.

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Benefits of Process Integration

- Heat Integration roots
  - Identify heat recovery targets and aid in synthesizing maximum heat recovery systems
  - Minimise utility demands and CO_2 emissions of a process
- Minimisation of resource consumption
  - Total Sites Optimisation
  - Supply Chains
  - Optimal time scheduling and tracking

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Heat Integration

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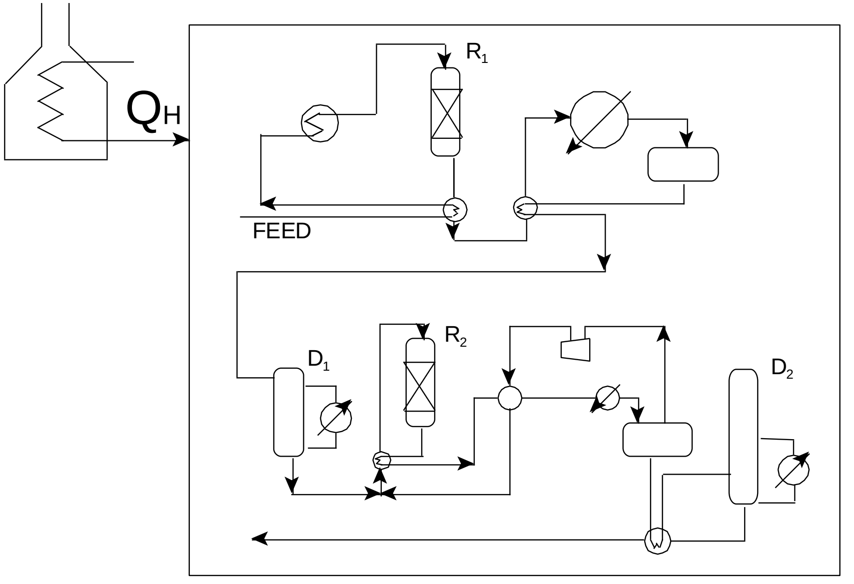
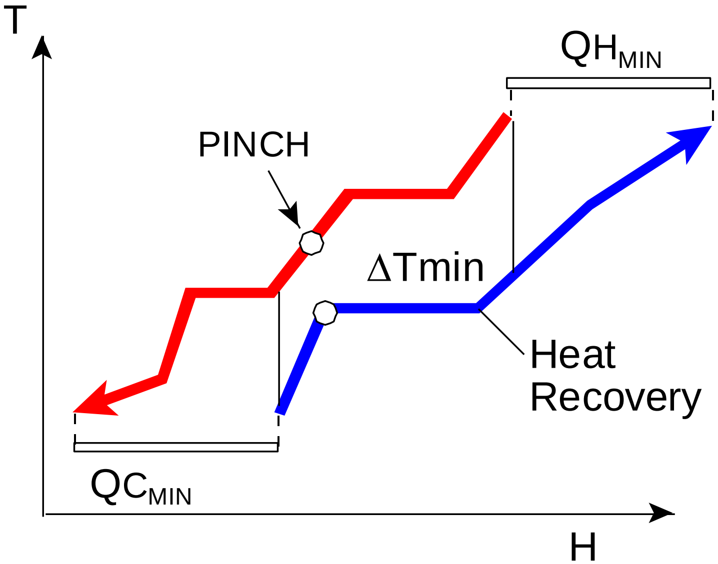
Heat Integration Principle



Existing Energy Consumption



Minimum Energy **Target**

Complicated Flowsheet ⇨ Simple Diagram

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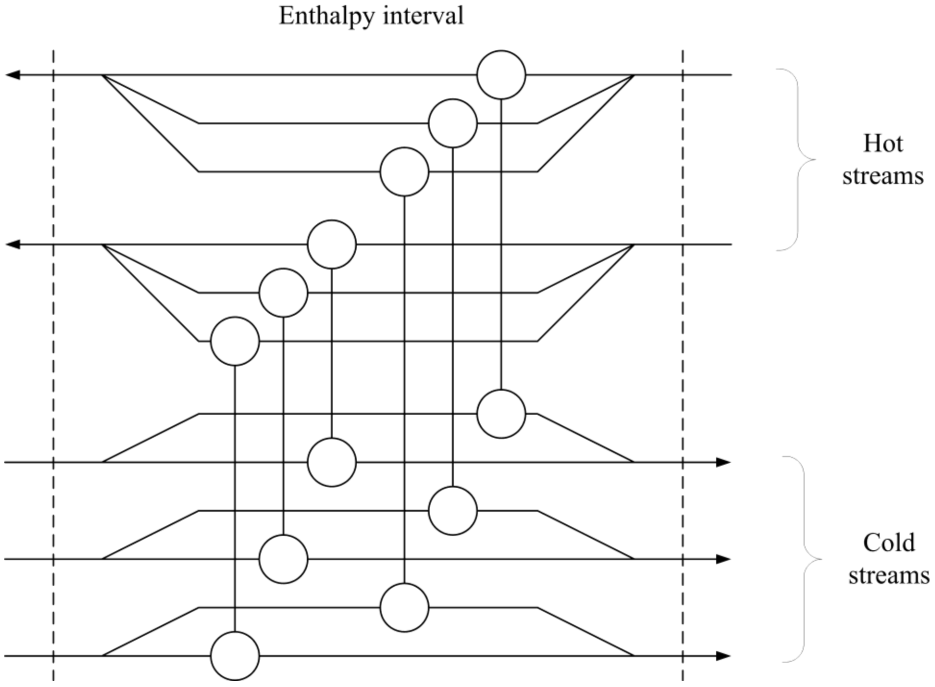
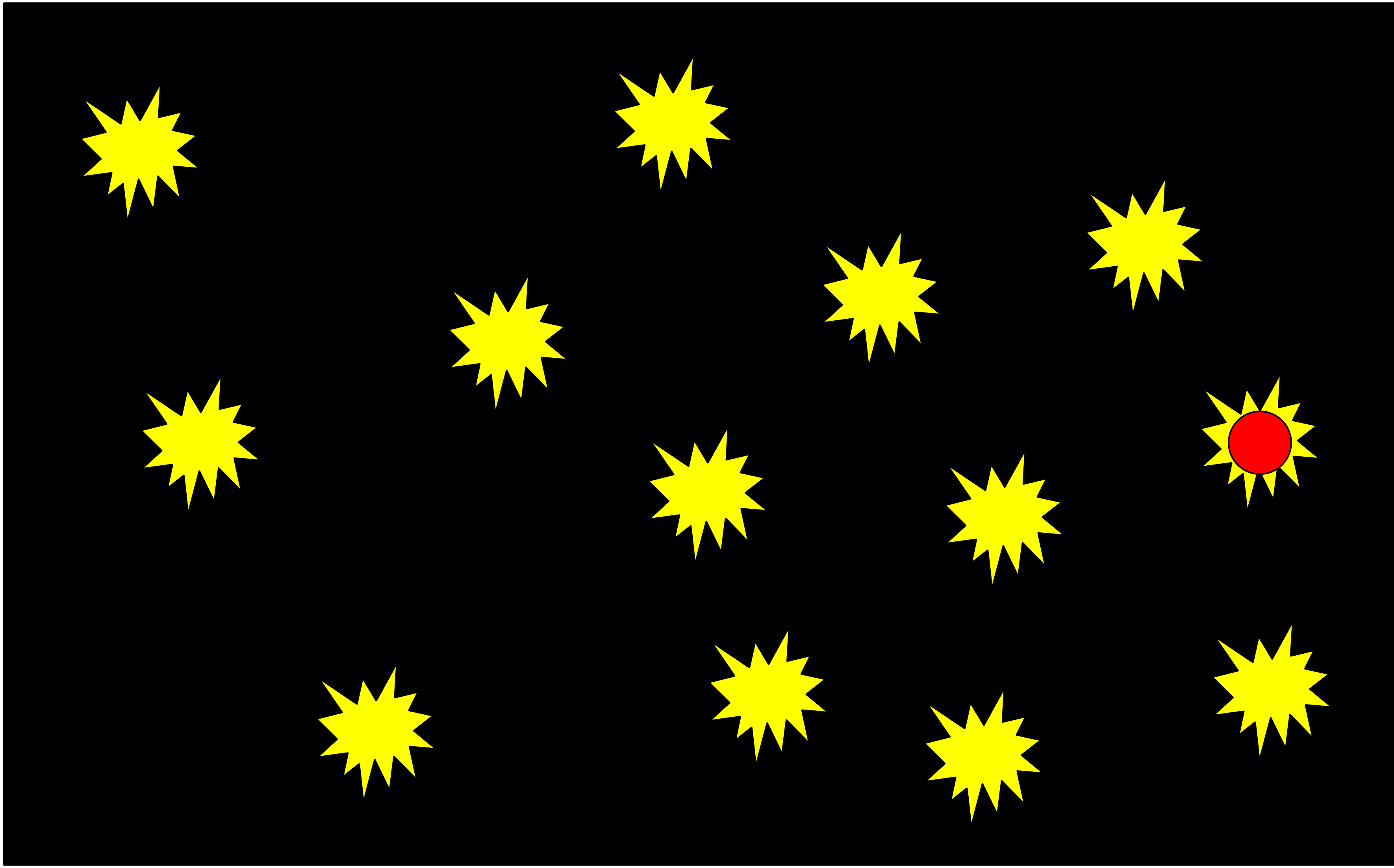
Construct superstructures and reduce them with optimisation solvers

Minimise TAC = {Operating Costs} + {Annualised Investment}

Subject to:
- Material and energy balances
- Capacity requirements
- Environmental limits
- Investment limits
- Social impact constraints
- Etc.



Without PI: Shooting in the dark



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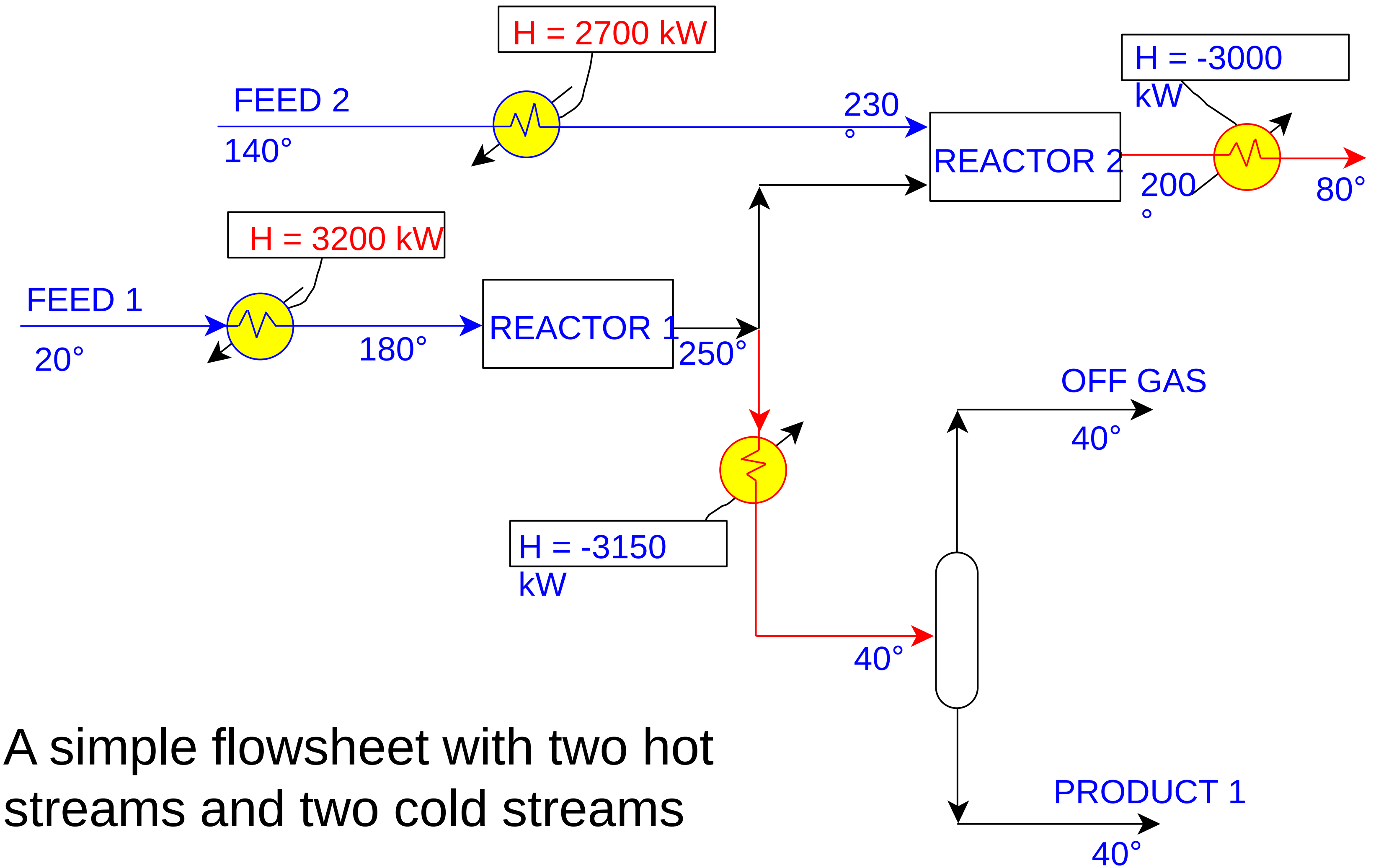

A simple flowsheet with two hot streams and two cold streams

Data Extraction

Stream	Type	Supply Temp. T_S(°C)	Target Temp. T_T(°C)	ΔH (kW)	Heat Capacity Flowrate CP (kW°C^{-1})
Reactor 1 feed	Cold	20	180	3200	20
Reactor 1 product	Hot	250	40	-3150	15
Reactor 2 feed	Cold	140	230	2700	30
Reactor 2 product	Hot	200	80	-3000	25

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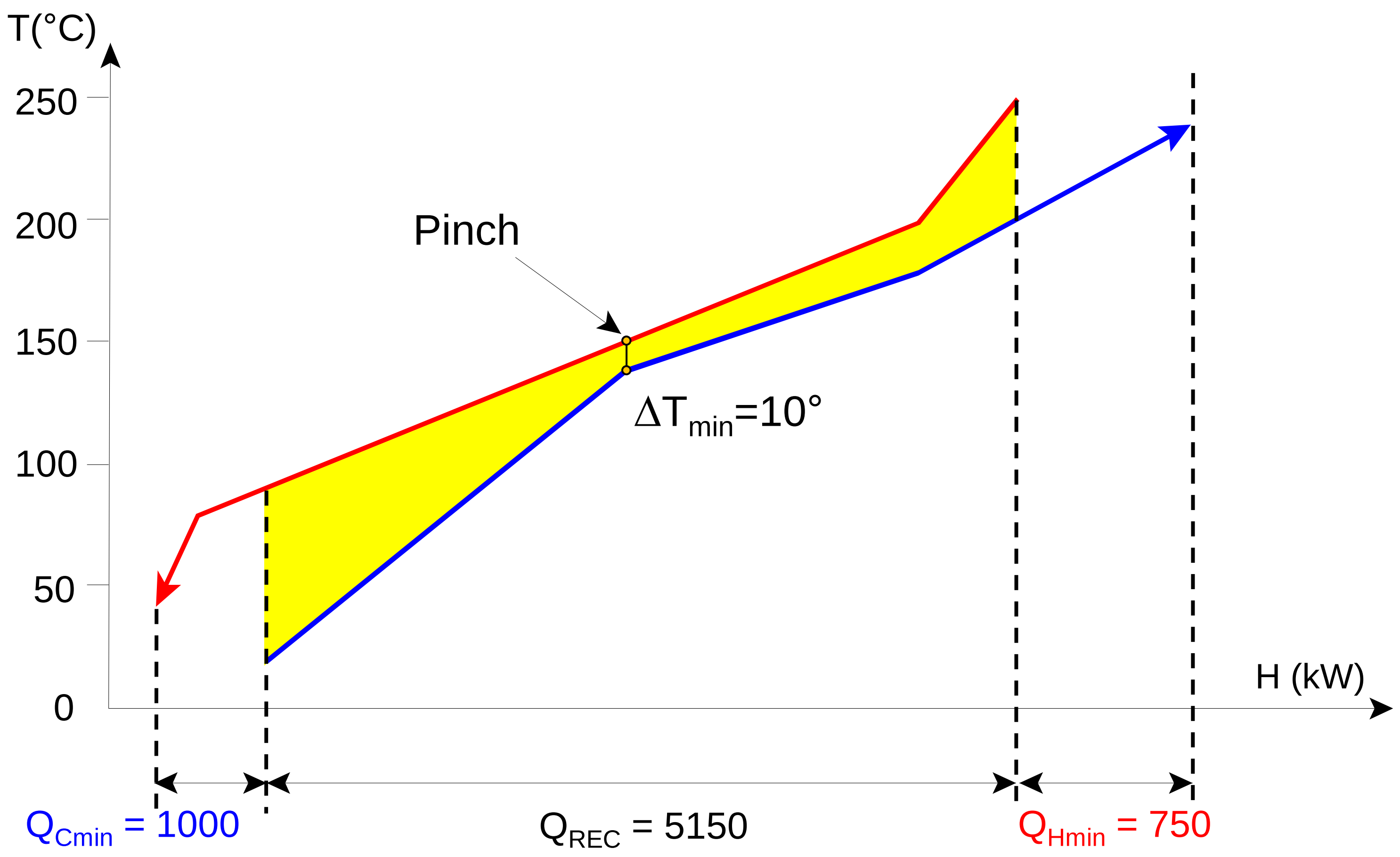
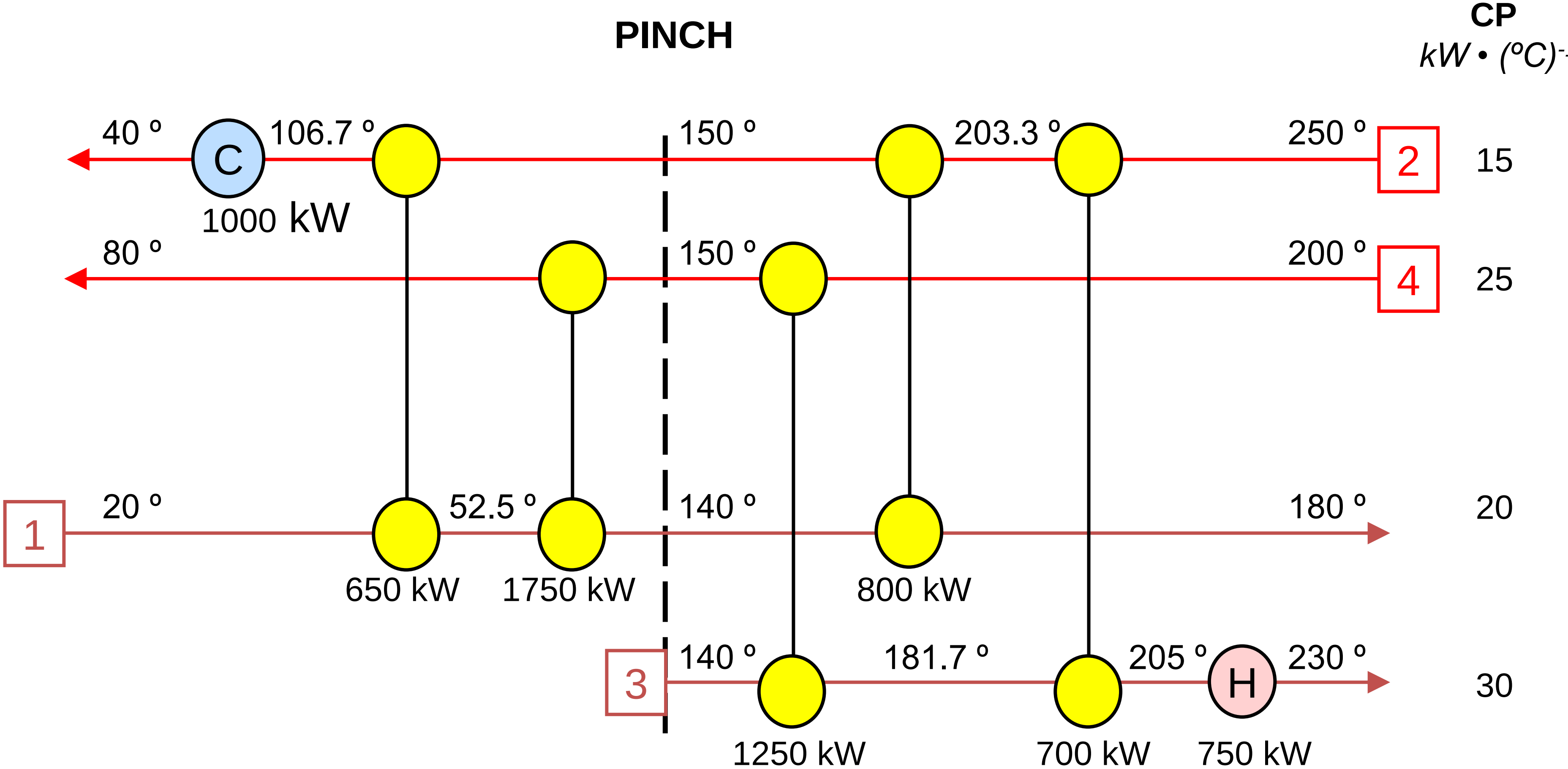
Composites Together for ΔT_{min} = 10 °C



Pinch Design Method



Q_{Hmin} = 750 kW Q_{Cmin} = 1000 kW

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Total Site (Heat) Integration

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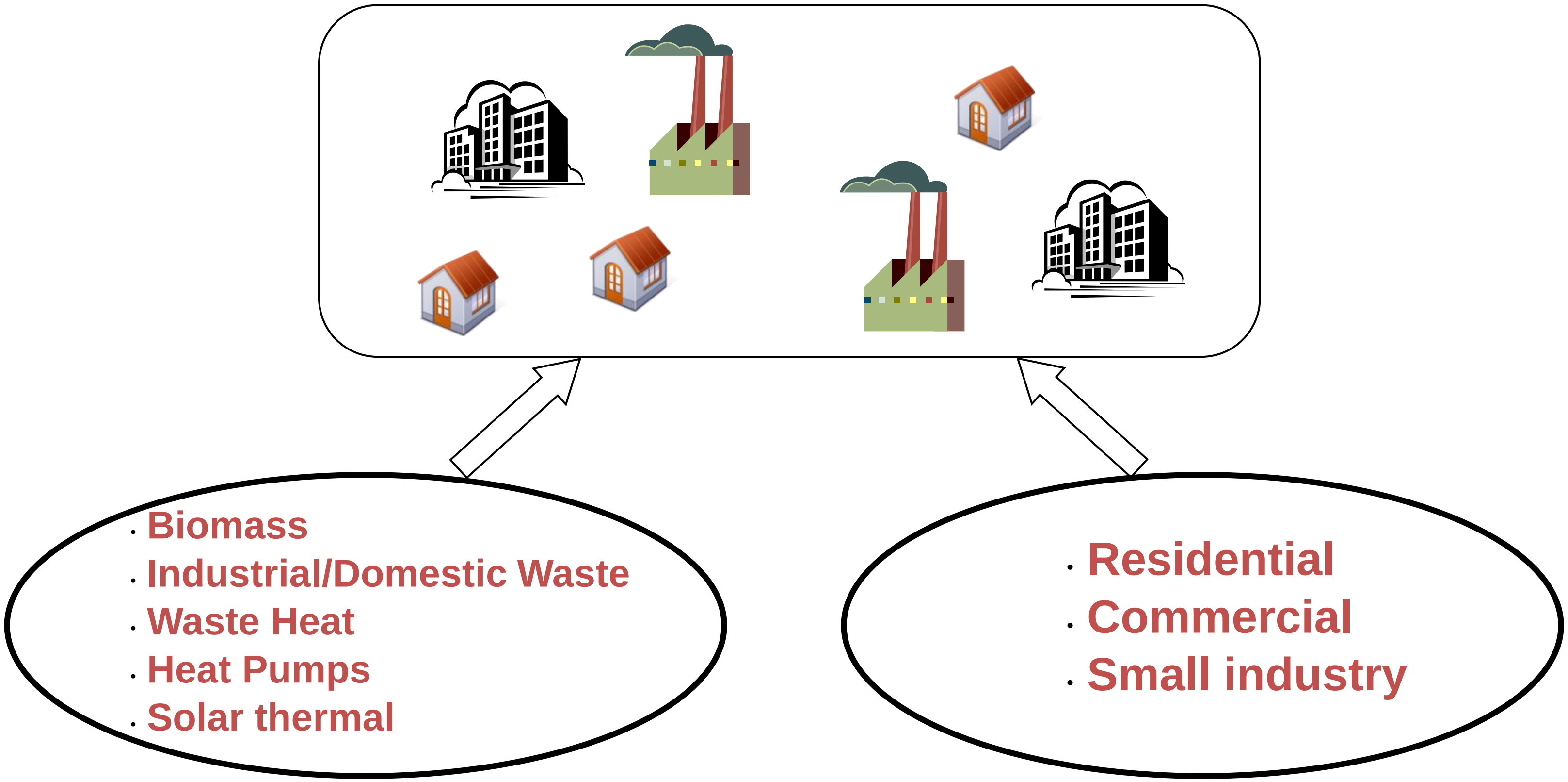
Industrial Sites



How to integrate?

Perry, Klemeš, Bulatov, Energy, 33, 1489-1497, 2008

Total Sites

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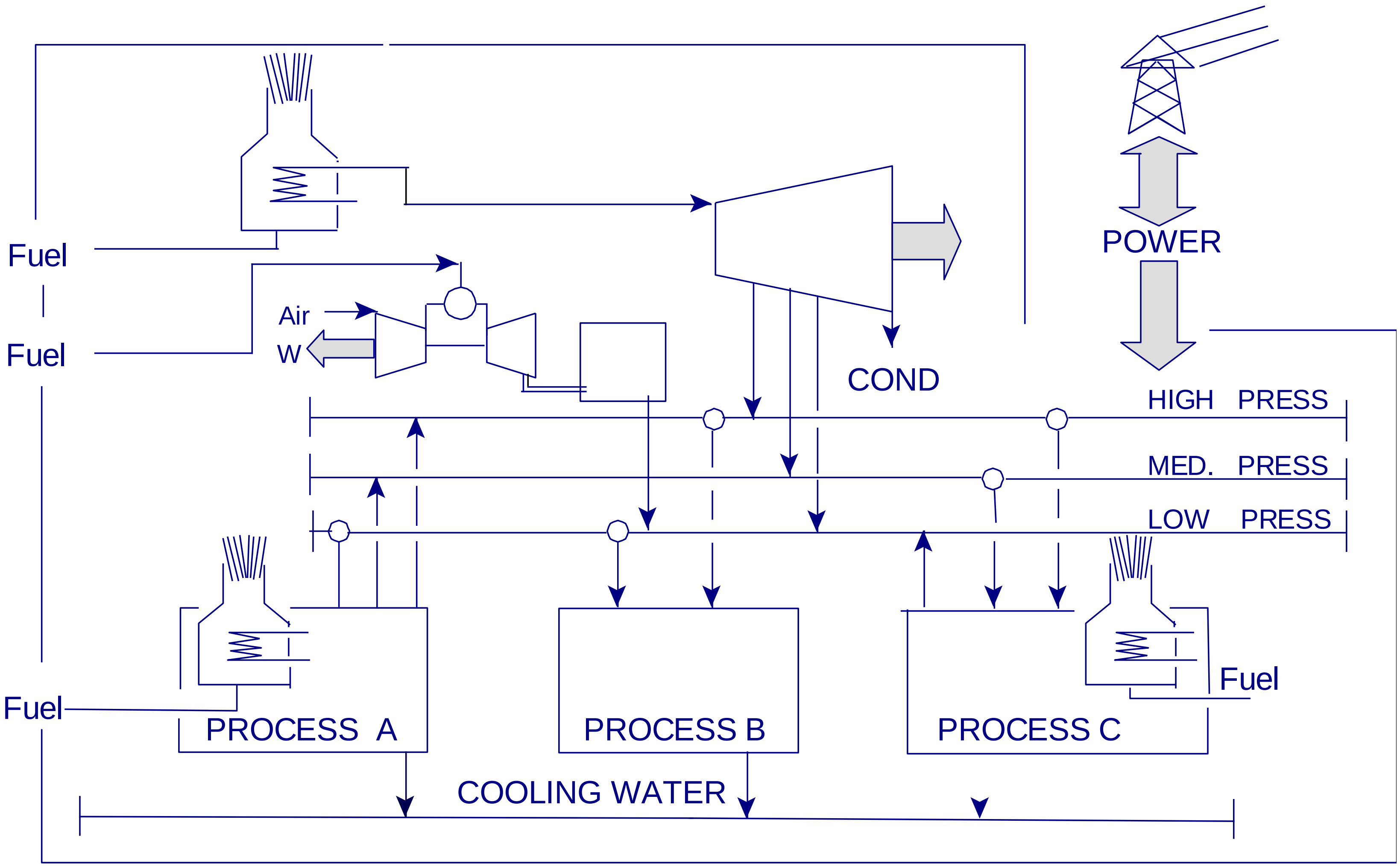
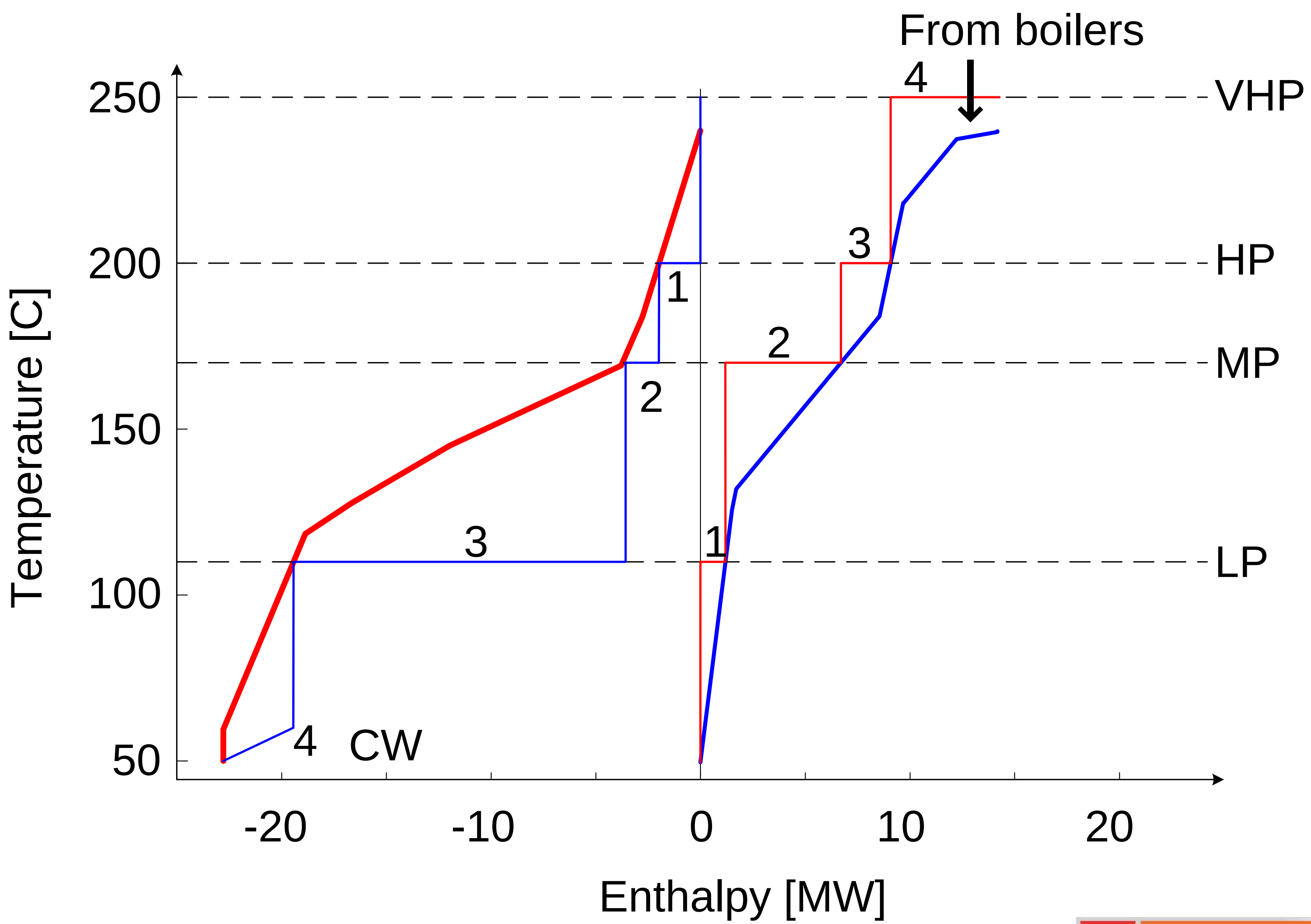


Total Site Targeting



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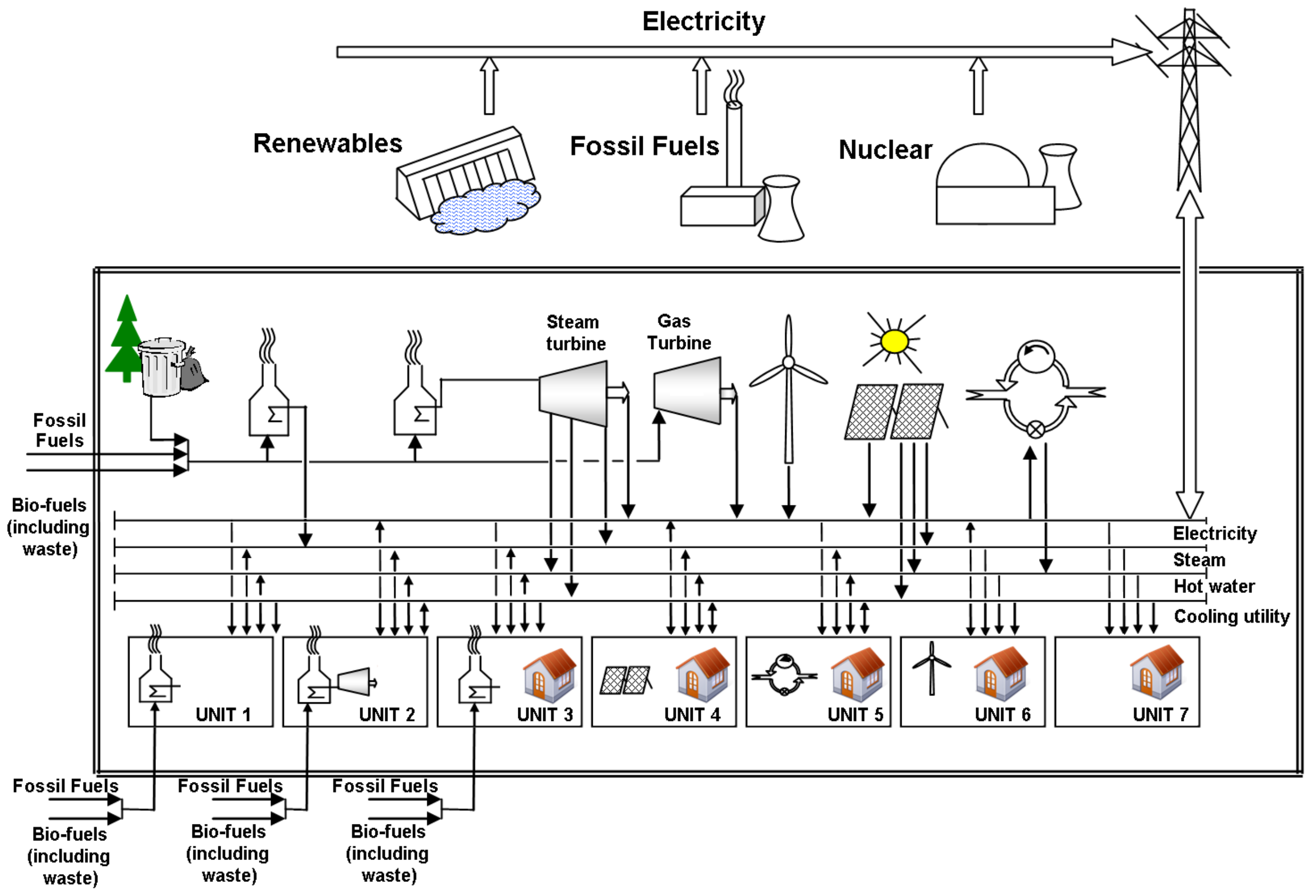

Perry, Klemeš, Bulatov, Chemical Engineering Transactions, 12, 2007, 593-598

Perry, Klemeš, Bulatov, Energy, 33, 1489-1497, 2008

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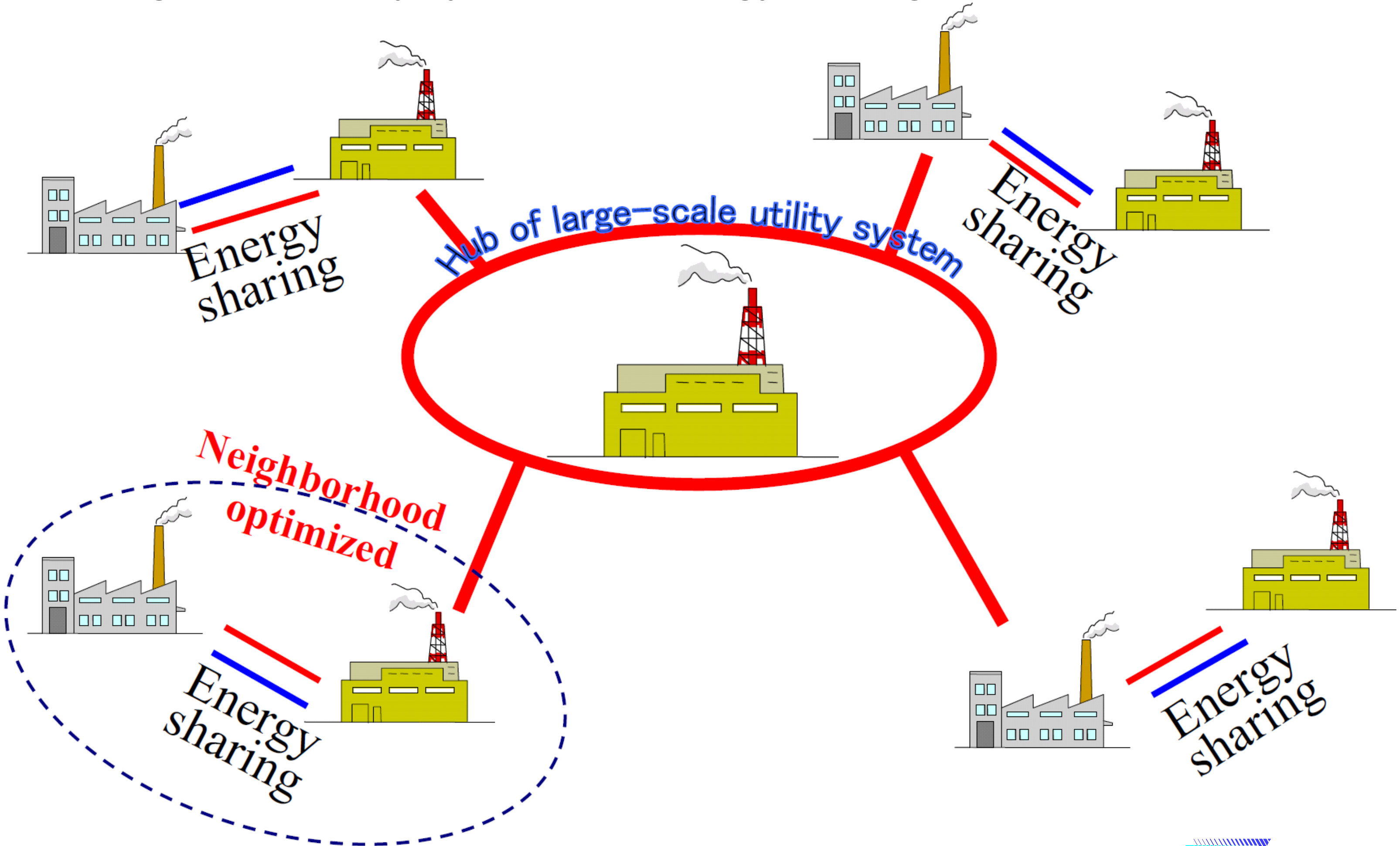
Hub of large-scale utility system and energy sharing



Matsuda, Proceedings PRES 2008, Vol 4, 1095 - 1096

CHIYODA CORPORATION
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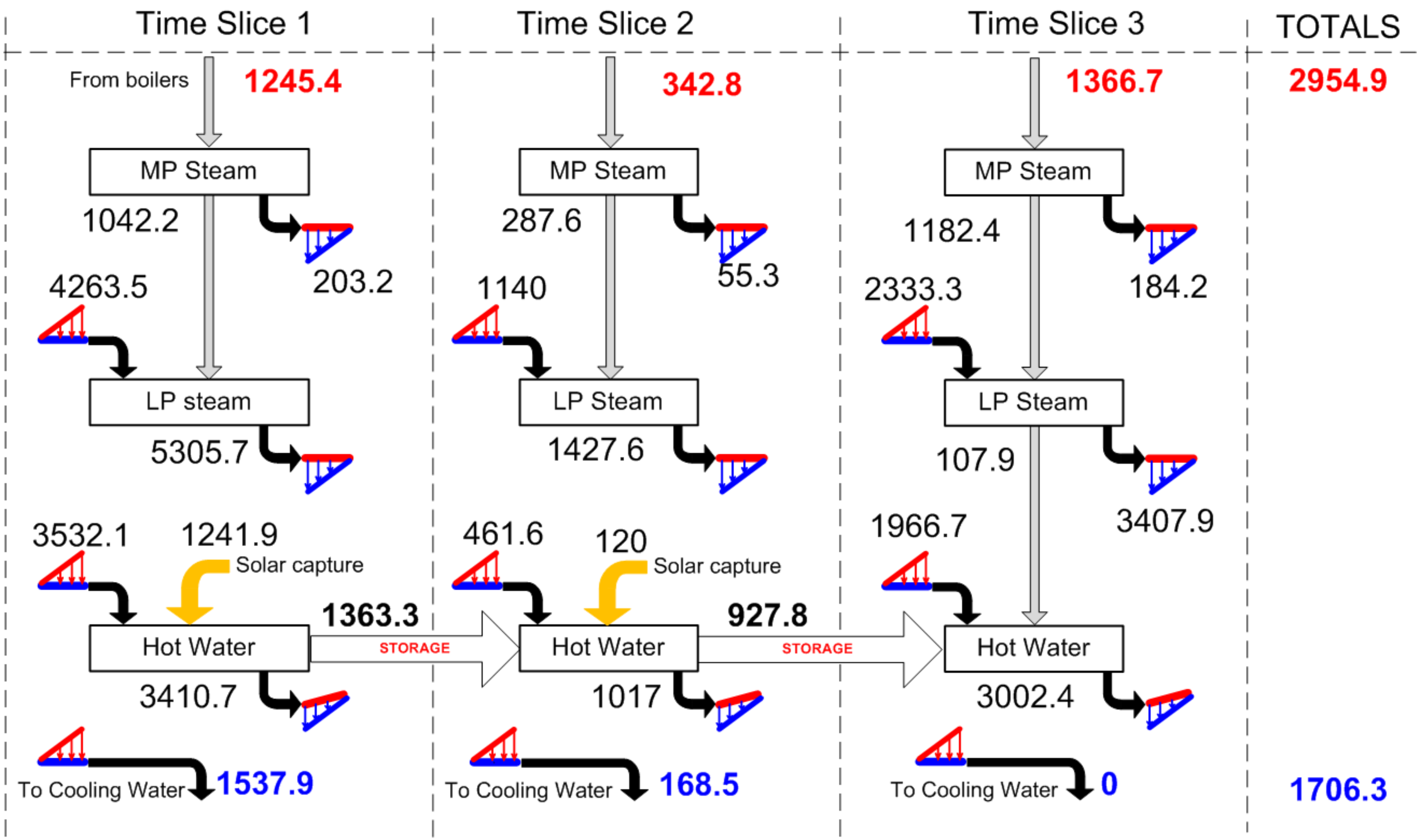
Total Site : Time-Varying Processes

All heat transfers are in [kWh]



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Total Site
Heat + Power Integration

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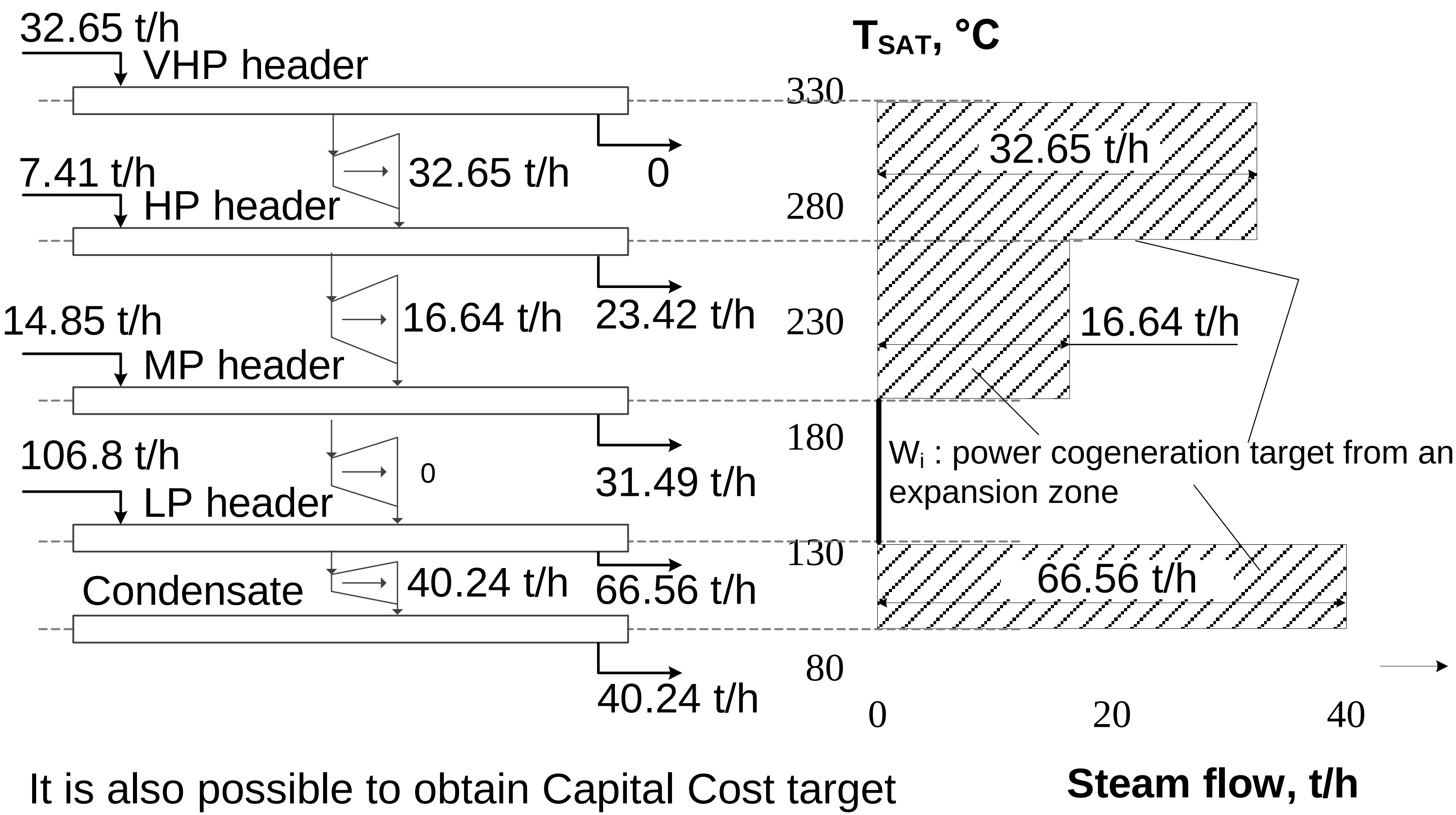
Cogeneration Targeting



It is also possible to obtain Capital Cost target

Boldyryev, S., Varbanov, P.S., Nemet, A., Klemeš, J.J., Kapustenko, P. , 2013. Capital cost assessment for total site power cogeneration, Computer Aided Chemical Engineering, 32, 361, 366

Combined Integration

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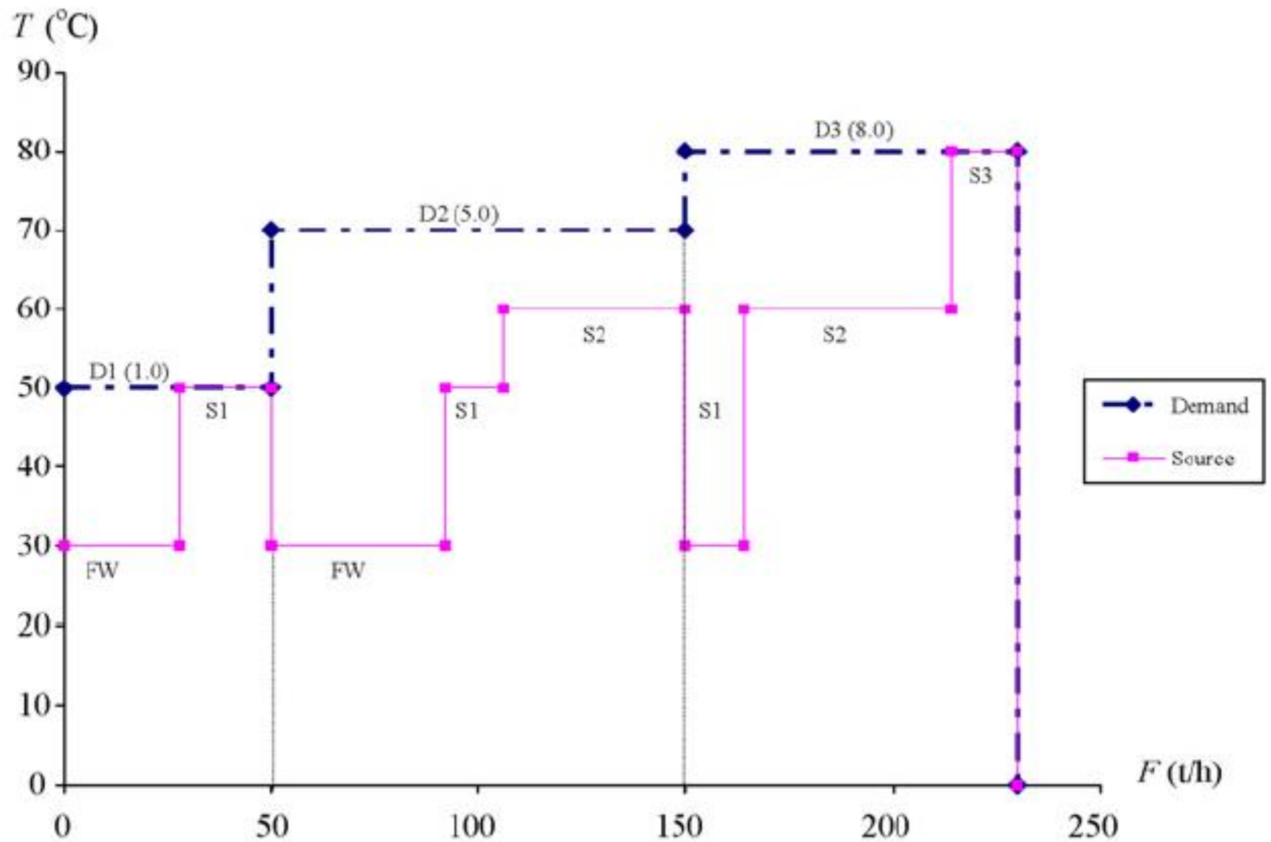
Combined Energy-Water Integration



Manan, Z.A., Tea, S.Y., Alwi, S.R.W., A new technique for simultaneous water and energy minimisation in process plant. Chemical Engineering Research and Design, Vol. 87, No. 11, (2009), pp. 1509–1519.

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Simultaneous Mass And Energy Minimisation

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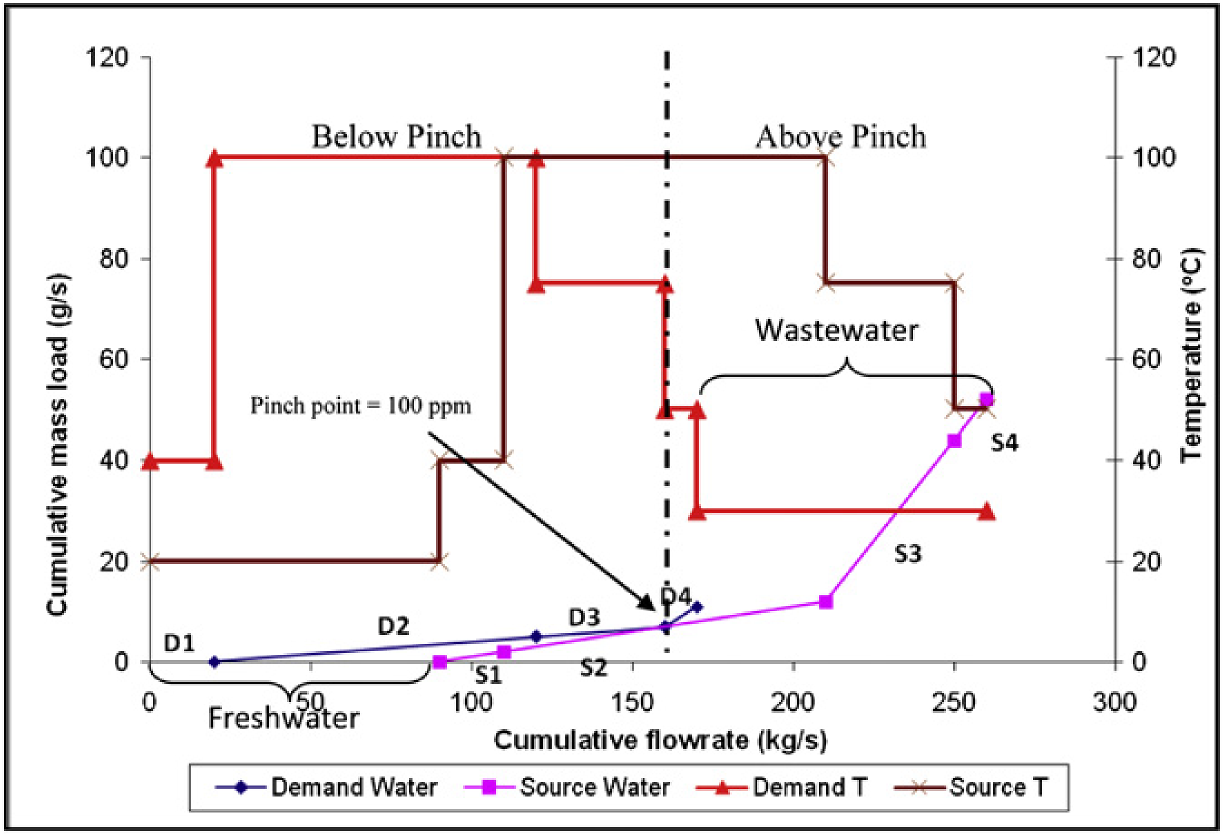
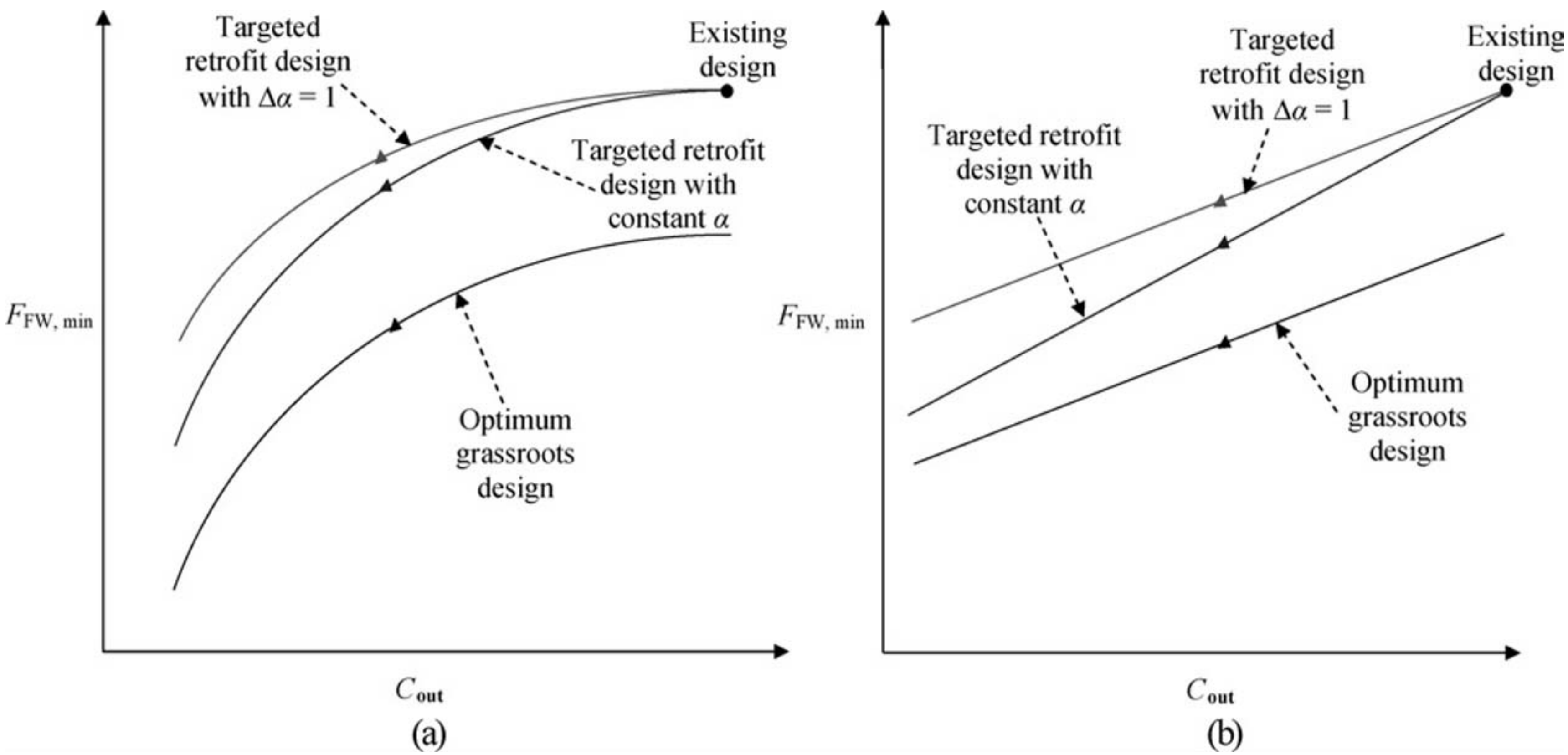


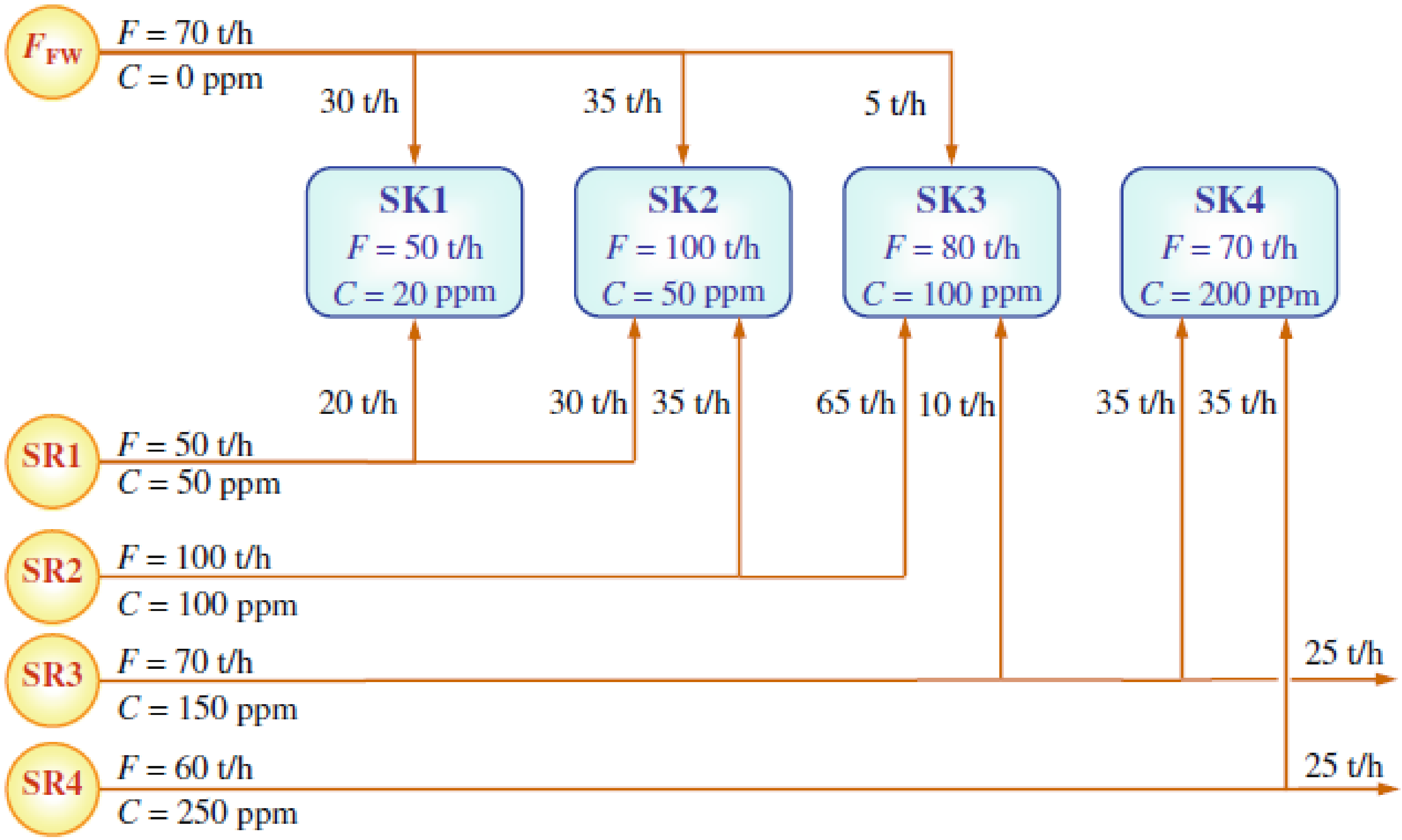
Wan Alwi S. R., Ismail A., Manan, Z. A., Bahiyah Z. A, New Graphical Approach For Simultaneous Mass And Energy Minimisation, Applied Thermal Engineering Journal, Vol. 31, No. 6-7, (2010), pp. 1021-1030.

Retrofit of Water Networks



Tan Y.L., Manan Z.A., Foo D.C.Y., Retrofit of Water Network with Regeneration Using Water Pinch Analysis, Process Safety and Environmental Protection, 85 (2007), 305-317.

Property Based Resource Conservation



Saw, S.Y., Lee, L., Lim, M.H., Foo, D.C.Y., Chew, I.M.L., Tan, R.R., Klemeš J.J., 2011. An extended graphical targeting technique for direct reuse/recycle in concentration and property-based resource conservation networks. Clean Technologies and Environmental Policy,, Volume 13, pp. 347-357.

PI for Supply Chains

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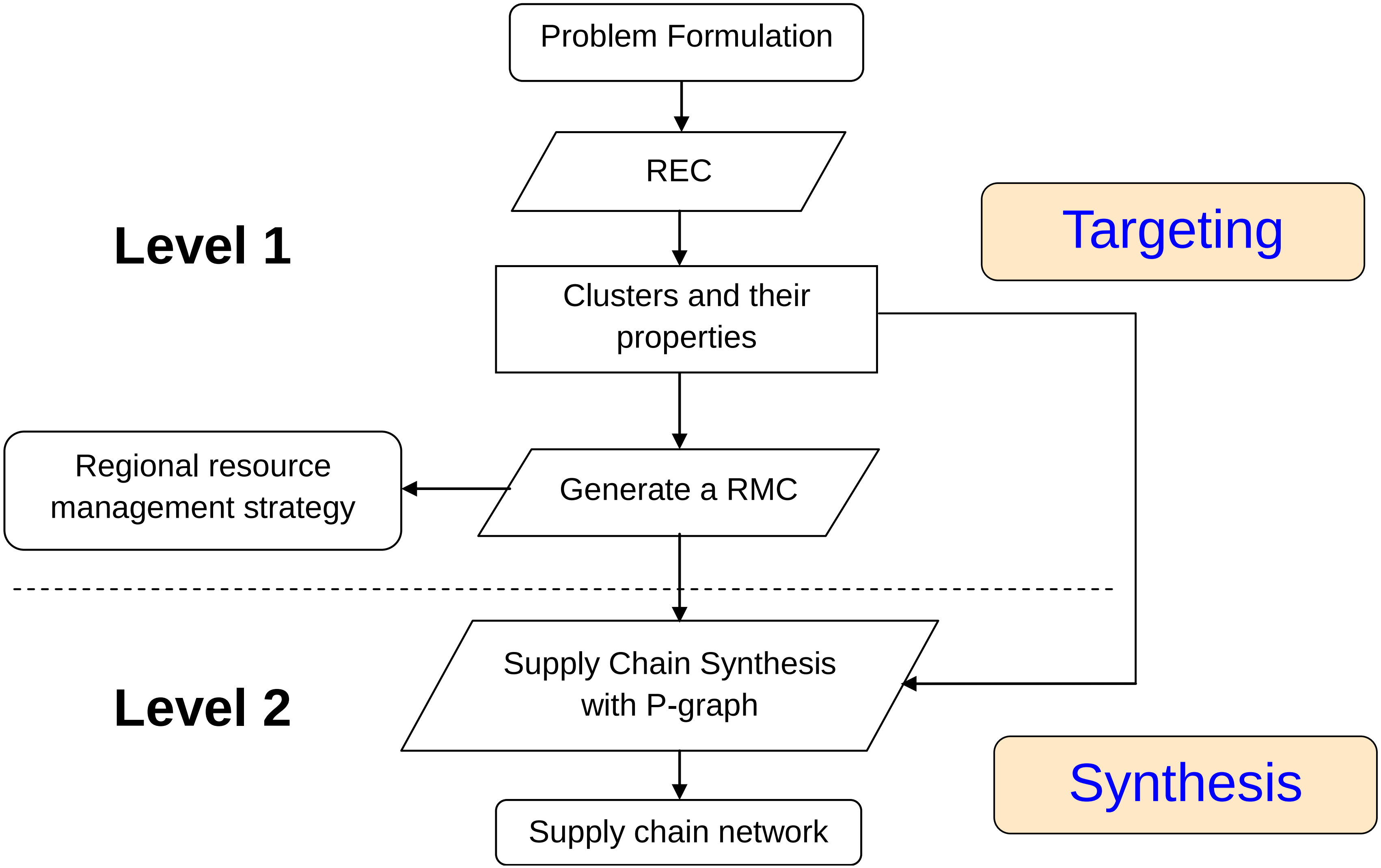
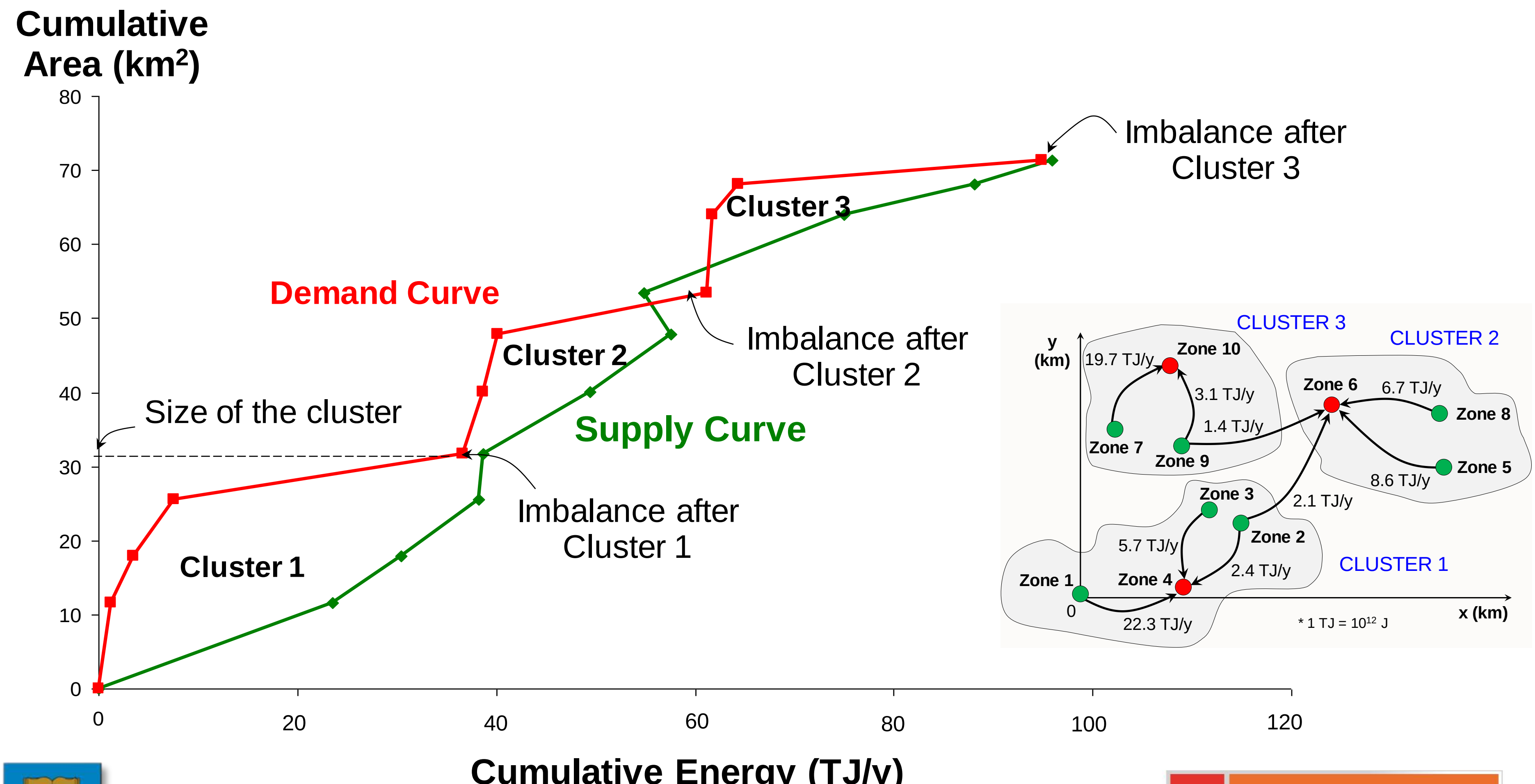
Two-Level Strategy



Targets: Regional Energy Supply Demand Curves



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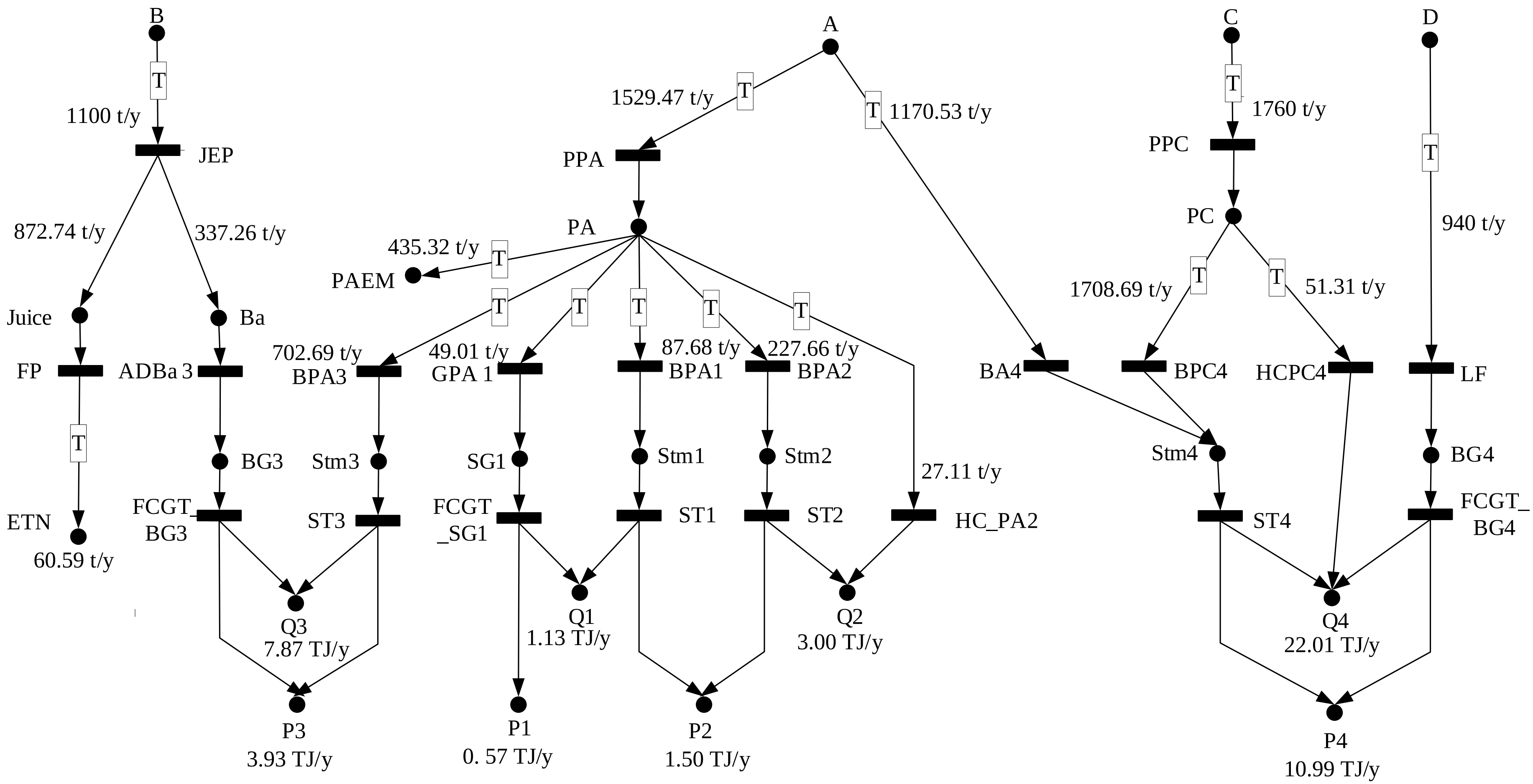
Uses P-graph



Challenges to Consider

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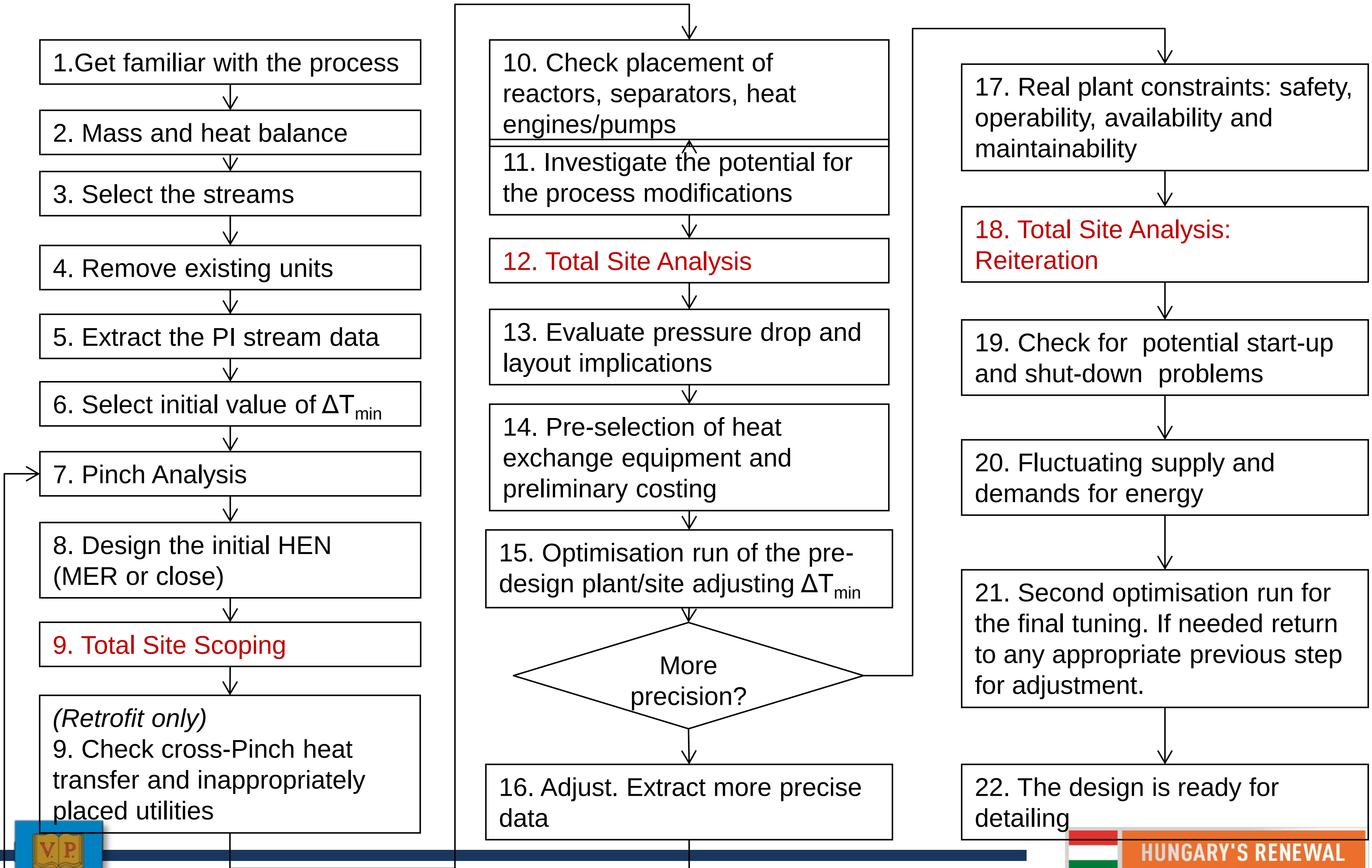
Optimisation and Process Integration (PI)

- PI sets out the strategy for designing and/or operating industrial processes, answering to the questions “WHAT is to be done?”
- Optimisation is used by PI, thus answering to the question “HOW to perform the task?”
- The issues tackled by PI are essentially complex optimisation problems
- PI can also provide quantitative targets to be aimed at or strictly achieved by engineers
- The targets can be used to partition the initial complex optimisation problems into sets of simpler ones, easier to solve

PI + OPT + IT ?

- These are three related but different areas of research and applications
- The major challenges are in building efficient teams
  - Mathematicians specialising in optimisation
  - Engineers and PI experts
  - IT professionals
- All these people come from very different backgrounds
- In a way speaking different “languages”
- A common “language” has to be used
- Efficient management of projects, time, people, etc.

Complex Algorithms



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Algorithms Complexity – Why?

- Algorithms treat complex problems
- Available models have limits and need to be combined
- Reflect available knowledge – people carry knowledge as experience
- Or interpret stored knowledge (from books, articles, repositories, software tools, etc.)

↓

Algorithms represent only one type of knowledge.

All contemporary knowledge is complex.

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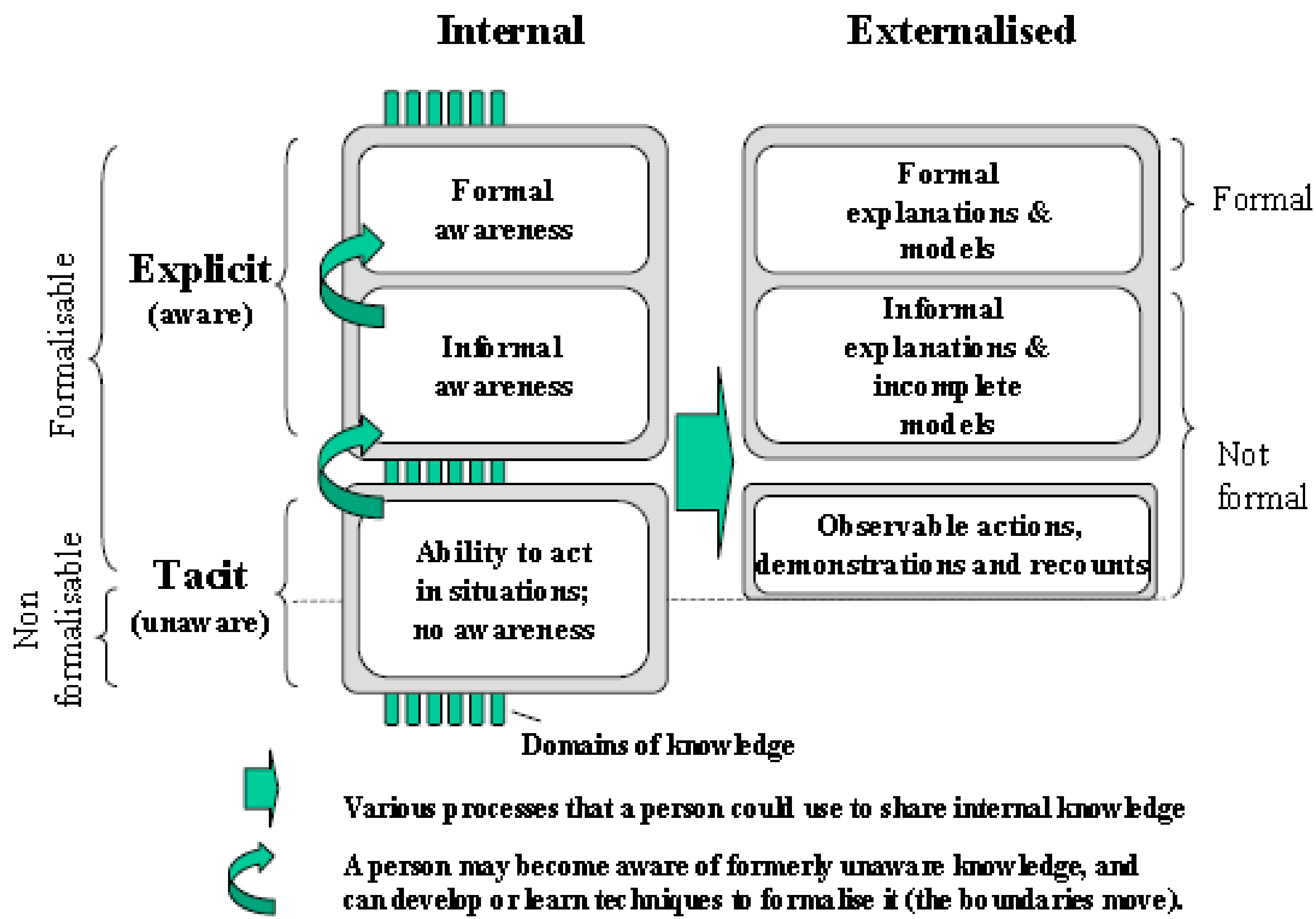
A More Formal Knowledge Model



Knowledge Management Challenges

- Knowledge management tools
- Capture all knowledge necessary for given applications or problem types
- Capable of storage and update of knowledge
- Efficient ways of practical knowledge application

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Resource Challenges

- Huge and growing energy and water demands
- Subject of considerable losses and a potential danger for the environment

Combination of large volumes and large loss rates

- There are implications and opportunities at several levels ranging from plant/site level up to regional and country level

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Summary and Suggestions

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Exploit Links as Synergies: An Example

- Energy-Water Nexus works **both ways** – not only in the direction of causing problems
- Energy and water savings should amplify each other.
- **It Can be used as a synergy mechanism**
- So far applied mainly at process level by the discussed methodologies
- Extend the scope of energy-water integration to site and supply chain level

Extend the Synergies

- Process Intensification – combine with Process Integration
  - to make them economically competitive
- Finding more synergy routes – e.g. chemical energy recovery in addition to direct heat or mass exchange.
- Apply renewables only after improving the system efficiency
- Minimise resource overheads resulting from logistics
  - Source water, energy, food as close to the users as possible
  - Reuse any waste heat and water that can be cleaned/recycled

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Benefits of Sourcing Regionally

- Short-medium term: direct energy savings from transportation
  - Substantial
  - Easily quantifiable
- Long-term and strategic
  - Improved supply security (quantifiable, but difficult)
  - Eventual higher employment locally (quantifiable, but difficult)
  - Avoiding/mitigating conflicts – not quantifiable, expected to improve safety and save costs of destruction and costs for military spending

Computational and Modelling Paradigms

NEW SZÉCHENYI PLAN

- Need to manage the existing and newly acquired knowledge more efficiently:
  - Uniform or compatible modelling languages
  - Powerful and efficient solvers
  - Proper business processes to maximise the use of human expertise and tacit knowledge
  - Knowledge Management systems to integrate the overall knowledge life cycle
- Novel modelling concepts inherently linked with efficient and effective visualisations

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Summary of Suggestions

- Use links as synergy mechanisms
- Extend the synergies
- Tackle the multi-dimensionality
- Tackle multi-disciplinariity
- Tackle complexity

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Conclusions

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- Sustainability requirements increase the challenges before industrial deign and operation
- Industrial systems have to be optimised – a complex task
- This has to be attacked by a combination of PI, optimisation, and IT
- Significant challenges in combining and managing knowledge

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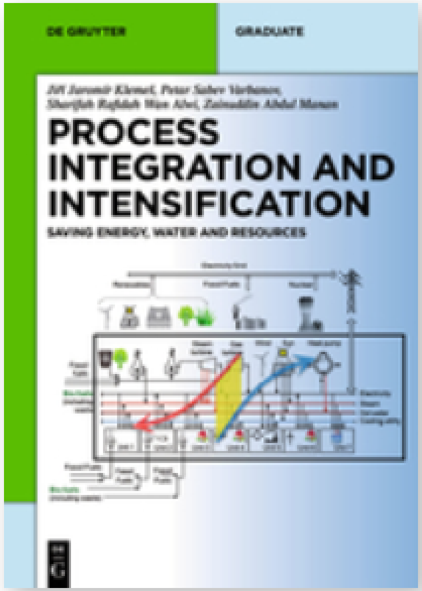

Jiří Jaromír Klemeš, Petar Sabev Varbanov,
Sharifah Radifah Wan Alwi, Zainuddin Abdul Manan

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Thank you for your attention!

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